A COMPARATIVE LIFE HISTORY STUDY OF FOUR SPECIES OF PIPEFISHES (FAMILY SYNGNATHIDAE) IN FLORIDA

By

JAMES DALTON BROWN

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Abstract of Dissertation Presented to the
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A COMPARATIVE LIFE HISTORY STUDY OF FOUR SPECIES OF PIPEFISHES (FAMILY SYNGNATHIDAE) IN FLORIDA

By

JAMES DALTON BROWN

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An investigation of four species of pipefishes (Syngnathus scovelli, Syngnathus floridae, Syngnathus louisianae, and Micrognathus crinigerus) inhabiting grass flats in the eastern Gulf of Mexico was begun in September, 1968. Morphological variation, seasonal abundance, reproduction, age, growth, and food of each species were examined and compared. This study involved regular field collections made in the Cedar Key, Florida, area and examinations of preserved specimens from various locations throughout the range of each species in Florida.

These species are widely distributed. S. scovelli ranges from the northern Florida Atlantic coast to southern Texas, Yucatan, and possibly Brazil, with freshwater populations present in the St. Johns and Santa Fe rivers, Florida, and Lake St. John, Louisiana. S.

floridae is distributed from Chesapeake Bay and Bermuda through the Bahamas to Panama. The range of *S. louisianae* extends from Chesapeake Bay to Florida, Texas, and Campeche, Mexico, and in Bermuda and Jamaica. *M. crinigerus* occurs in the Bahamas and from Miami to Yucatan and possibly Brazil.

Each species is figured and described. Sexual dimorphism is demonstrated for *S. scovelli* and *S. floridae*. Available mature specimens of *S. louisianae* and *M. crinigerus* are too few in number for valid sexual comparisons.

A detailed examination of *S. scovelli* yielded considerable geographical variation in morphology, apparently associated with temperature and salinity. Numbers of dorsal fin rays and tail rings tend to increase in northward areas. Head length/snout length ratio is lower in northern and freshwater populations, suggesting that both low temperature and decreased salinity result in the development of a longer snout. Morphologically, the freshwater population in the Santa Fe River is the most distinct, suggesting genetic isolation from saltwater populations in the Gulf of Mexico.

These pipefishes attain sexual maturity over a wide size range. Males usually achieve maturity, as determined by a completely developed brood pouch, at a smaller size than females. Sexual maturity in females is revealed by the presence of ripe ova in the body cavity.

Nearly continuous breeding is indicated in many areas for these pipefishes. Individuals of *S. scovelli* and *S. floridae* in breeding condition occurred at Cedar Key during all seasons, with spring and fall peaks in reproduction indicated for both species. Limited

evidence suggests that *S. louisianae* probably also breeds year round. *M. crinigerus* apparently has a shorter spawning season, lasting from April through September.

Sex ratio varies seasonally in *S. scovelli* and *S. floridae*. At Cedar Key mature females of *S. scovelli* slightly exceeded mature males in abundance from late fall to early spring, but males greatly outnumbered females from late spring through early fall. Females of *S. floridae* outnumbered males during every month except one. This difference was sizable in winter; during summer females exceeded males only slightly.

The number of embryos carried by pregnant males depends largely upon the size of the male. Maximum brood counts obtained in this study were 175 embryos for *S. scovelli*, 886 for *S. floridae*, 898 for *S. louisianae*, and 41 for *M. crinigerus*.

Length-frequency analyses of Cedar Key specimens indicate that *S. scovelli* and *S. floridae* grow to sexual maturity and breed within a year of birth. Most individuals probably live less than one year. Age and growth in *S. louisianae* and *M. crinigerus* are probably similar to this.

The diet of these pipefishes consists almost entirely of microcrustaceans. Larger individuals usually utilize amphipods and small shrimp, and smaller specimens feed on copepods and amphipods. Other food items taken occasionally include isopods, ostracods, and larval pipefishes. The relative importance of each type of food varies among the four species, which should reduce interspecific competition for food.

INTRODUCTION

The inshore grass flats of the eastern Gulf of Mexico are inhabited by a large and diverse assemblage of fishes. Collecting efforts in these areas reveal that one of the more conspicuous elements of this fauna consists of the pipefishes, members of the family Syngnathidae. Four species of pipefishes are found regularly in the vicinity of Cedar Key, Florida, where the University of Florida Marine Laboratory is located. The common and scientific names of these as established by the American Fisheries Society (1970) are Gulf pipefish, Syngnathus scovelli (Evermann and Kendall), Dusky pipefish, Syngnathus floridae (Jordan and Gilbert), Chain pipefish, Syngnathus louisianae Günther, and Fringed pipefish, Micrognathus crinigerus (Bean and Dresel). The occurrence of the Whitenose pipefish, Corythoichthys albirostris Heckel, in this area has been demonstrated by the collection of a single specimen. In addition to the five species of pipefishes, two other syngnathids are present in the Cedar Key area. These are the Dwarf seahorse, Hippocampus zosterae Jordan and Gilbert, and the Lined seahorse, Hippocampus erectus Perry.

The family Syngnathidae is widely known as a result of the popularity of seahorses as marine aquarium specimens and an unusual reproductive specialization involving the incubation of embryos in a brood pouch by male members of the family. Available literature on most species consists of the original description and a few locality records in faunistic studies. The four species under investigation were all described prior to 1900. The Gulf pipefish, S. scovelli, was described by Evermann and Kendall (1896) from specimens taken at Shamrock Point, Corpus Christi, Texas. Florida specimens from Marco and Key West were also included in the original description. The Dusky pipefish, S. floridae, was described by Jordan and Gilbert (1882) from Pensacola Bay, Florida. Syngnathus mckayi, described by Swain and Meek (1884) from Key West specimens, was synonymized with S. floridae by Herald (1965). S. floridae includes several poorly defined subspecies (Herald, 1942, 1965). These are S. f. hubbsi, S. f. floridae, S. f. mckayi, and S. f. nesiotes. S. louisianae, the Chain pipefish, was described by Günther (1870) from a single specimen from New Orleans, Louisiana. Bean and Dresel (1884) described M. crinigerus, the Fringed pipefish, from Pensacola, Florida.

In the past 35 years several significant papers on syngnathids have been published in the United States. The most prominent worker in this area was Herald (1940, 1941, 1942, 1959, 1965) who published several studies of the classification and phylogeny of American pipefishes. A limited number of life history studies also appeared during this time. Strawn (1958) investigated the life history of H. zosterae at Cedar Key, Florida, and Powell and Strawn (1963) published a brief paper on the biology of M. crinigerus on the west coast of Florida. The biology of S. scovelli was investigated in Florida by Joseph (1957) and in Louisiana and Mississippi by Whatley (1969). In an earlier part of this century Gudger (1905) made a detailed study of the reproduction and embryology of *S. floridae* at Beaufort, North Carolina.

Several faunistic studies of the coastal fishes of Florida have included brief life history data on the four species of pipefishes under investigation. A prominent paper on the fishes in the vicinity of Cedar Key by Reid (1954) presented some information of the biology of these species. Fishes occurring in brackish-water marshes at Cedar Key and Bayport on the west coast of Florida were studied by Kilby (1955), but data on pipefishes were limited since these species are not well represented in coastal marshes. Studies of the fishes of Alligator Harbor by Joseph and Yerger (1956) and Tampa Bay by Springer and Woodburn (1960) provide comparisons with the studies by Reid and Kilby. Freshwater populations of *S. scovelli* received attention by McLane (1955) and Hellier (1967) in studies of the fishes of the St. Johns and Santa Fe rivers, respectively.

Because of the paucity of basic information on the biology of pipefishes, an investigation of the life history and ecology of the four most common species found in the Cedar Key area was begun in September, 1968. *C. albirostris* was omitted from investigation since only the single specimen has been recorded at Cedar Key. The aspects of their biology examined were morphological variation, seasonal abundance, environmental factors, reproduction, age, growth, and food.

Both field collections and laboratory techniques were employed in the course of the study. Specimens representing populations of these species throughout their geographical ranges in Florida were examined in order to provide a more complete understanding of the natural history of these fishes. This portion of the study was expanded to include an investigation of the geographical variation in the interesting and widespread *S. scovelli* in Florida. Most of the study was conducted at the University of Florida Marine Laboratory on Seahorse Key, near the town of Cedar Key, and in the Department of Zoology, University of Florida. The terminal stages were completed in the Science Department, Indian River Community College, Fort Pierce, Florida.

MATERIALS AND METHODS

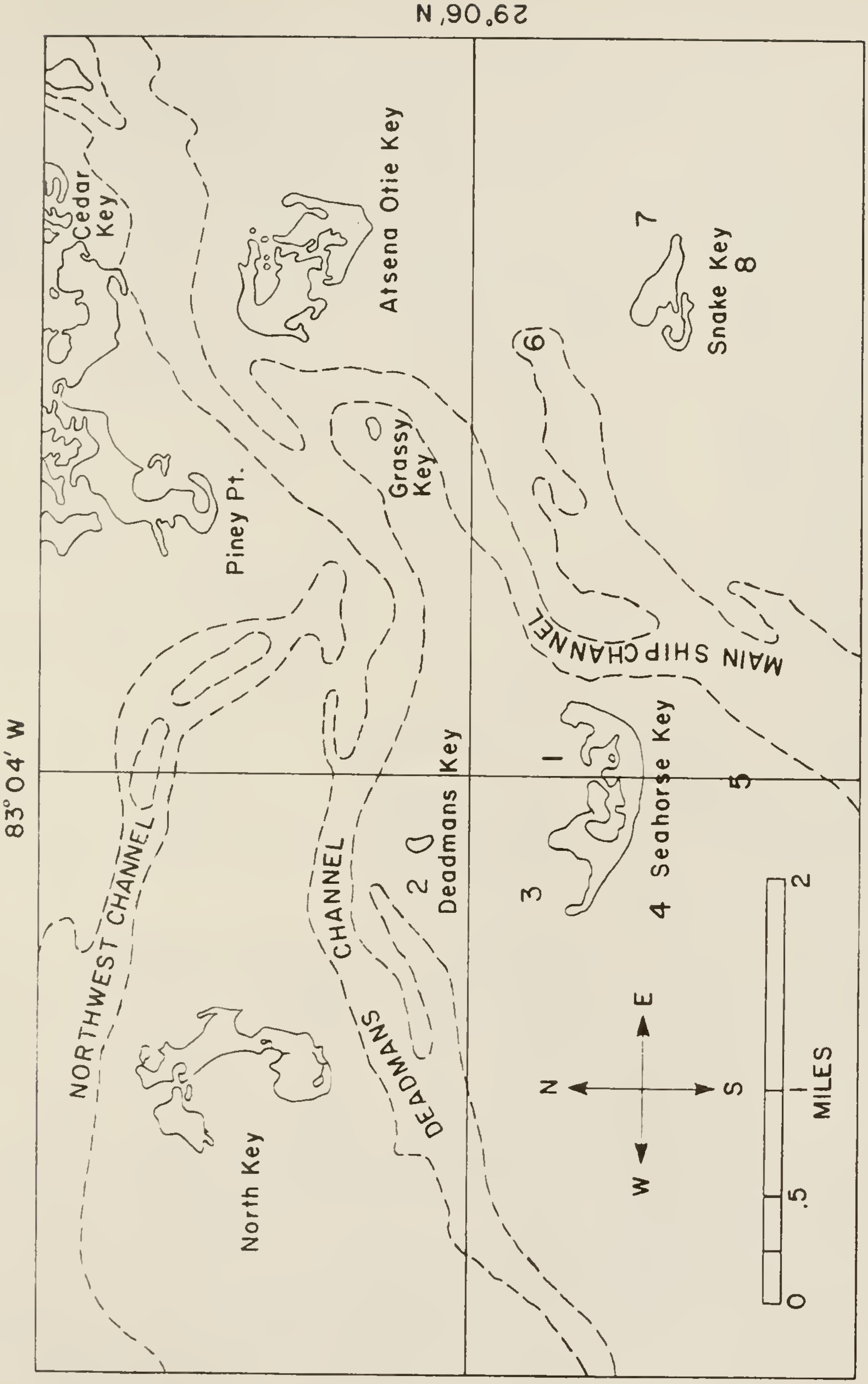
Field Equipment and Methods

All field work was done in the vicinity of Cedar Key, Florida. Eight collecting stations were established near Seahorse, Deadmans, and Snake keys (Figure 1). Stations 1, 4, and 5 are located on the shallow flats described by Reid (1954). Depth at these sites is about two to three feet at mean low tide. All three stations are occasionally exposed during extremely low tides, but the shallow Station 1 is most often subjected to this. The bottom at these areas consists mainly of mud, sand, and shell debris. Vegetation disappears from these locations as cold weather approaches, and these shallow flats remain barren during winter. Station 1 is relatively protected from offshore winds and currents by the crescent-shaped Seahorse Key, but Stations 4 and 5 are fully exposed to these.

Stations 2, 3, 7, and 8 are located on deep flats (Reid, 1954). Depth here is four to six feet at mean low tide, and these sites are under two to three feet of water at lowest tides. Bottom conditions are similar to those on the shallow flats. Vegetation decreases here in winter also, but sparse amounts of sea grasses and algae are usually present throughout winter.

Station 6 is the only deep-water station included in this study.

Figure 1. Map of the Cedar Key, Florida, area showing eight collecting stations in the vicinity of Seahorse, Deadmans, and Snake keys.


29°06' N
83°04' W
Cedar Key
Atsena Otie Key
Piney Pt.
Grassy Key
NORTHWEST CHANNEL
DEADMANS CHANNEL
MAIN SHIP CHANNEL
North Key
Deadmans Key
Seahorse Key
Snake Key
1
2
3
4
5
6
7
8
N
S
E
W
0
.5
1
2
MILES

Depth at this location is estimated to be around 12 feet at mean low tide. Bottom material here consists primarily of shell debris.

Stations 1-5 were sampled twice monthly, weather permitting. Stations 6-8 were established for the purpose of obtaining monthly samples; however, these three stations were actually visited irregularly, particularly during winter months. Exploratory collections were made occasionally in the deep channels in the Cedar Key area. Field work was conducted from September, 1968, to December, 1969; and collections were made during every month except October, 1968.

Field collections were made with a beam trawl that consisted of two metal runners five feet apart, connected with a 2x4-inch wooden bar. A net bag with a 1/4-inch mesh was attached to the bar and runners and extended seven feet behind the runners. The bottom of the mouth of the bag was weighted with a chain to keep it on bottom.

The beam trawl was pulled in a semicircle over a period of ten minutes for each sample. A fiberglass boat, 14 feet in length and powered by a 20 horsepower outboard engine, was used to pull the trawl. At the end of ten minutes the trawl was lifted into the boat and the catch sorted. Pipefishes were preserved in 10% formalin and transported to the laboratory.

Water and air temperatures were taken after each collection with a standard mercury-filled thermometer. Water samples were taken in plastic bottles and returned to the laboratory for salinity determinations with density hydrometers.

Laboratory Techniques

Specimens taken in field collections were transferred to 40% isopropyl alcohol for permanent preservation. The species were sorted, sexed when possible, and measured. Counts and measurements are described in detail later in the section on morphological variation.

All males were examined for the presence of embryos, and brood counts were made on individuals selected randomly from each month's catch. Egg diameters were determined with a micrometer disc mounted in a stereomicroscope. Females were dissected to detect the presence of developing ova.

Representative samples of each species throughout their ranges in Florida were also examined. Specimens deposited in collections at the Rosenstiel School of Marine and Atmospheric Sciences, Tropical Atlantic Biological Laboratory, Florida State Museum, and Florida State University were utilized in this portion of the study.

Statistical analyses were made with a Spectra 70/35 computer at Palm Beach Junior College.

DESCRIPTION OF THE CEDAR KEY AREA

The Cedar Key area is located in the eastern Gulf of Mexico at approximately Latitude 29°06' N and Longitude 83°04' W (Figure 1). This is about 90 miles northwest of Tampa, Florida. The mouth of the Waccasassa River lies approximately 14 miles to the east, and the mouth of the Suwannee River is roughly 11 miles northwest of Cedar Key. Topographically this region consists of a group of marsh and offshore islands surrounded by extensive shallow areas or flats (Figure 1). These flats support dense beds of Turtle grass, *Thalassia testidinum*, Manatee grass, *Syringodium filiforme*, Cuban shoal weed, *Diplanthera wrightii*, and Widgeon grass, *Ruppia maritima*, during summer months, but they are virtually barren during winter months except for various algae that appear in late winter. A common feature of these shallow areas is the numerous oyster bars found at various locations.

This area of islands and flats is dissected by deep channels which converge near the town of Cedar Key (Figure 1). Channel bottoms are usually composed of mud and shell debris with rocky outcroppings found in several spots.

This area provides a rigorous environment for its inhabitants. Salinity is quite variable due to the proximity of the Suwannee and Waccasassa rivers, and the water temperature range between summer and winter is fairly wide. Organisms living on the flats have little protection from strong tidal and wave actions. During winter months the barren shallow flats are often exposed to air during low tide. These environmental factors are discussed in relation to the pipefishes later.

DISTRIBUTION

The range of *S. scovelli* extends from the northern Atlantic coast of Florida to possibly Brazil. It occurs around the southern tip of Florida and throughout the northern Gulf of Mexico. Although generally considered to be a marine species, freshwater populations are known from several localities. Herald (1942) listed the distribution of *S. scovelli* to be from Matanzas, Florida, to Corpus Christi, Texas, with a doubtful record from Albrohlos Island, Brazil. Earlier Hubbs (1936) had extended the range of this species to the Yucatan Peninsula. Several fishes, such as *Gobionellus smaragdus* and *Gobionellus stigmaticus*, are known to possess an antitropical distribution (C. R. Gilbert, pers. comm.); and subsequent work may show that *S. scovelli* also exhibits this type of distribution. Tagatz (1968) reported *S. scovelli* to be distributed through the St. Johns River in northeastern Florida. This species occurred in collections made in both saltwater localities and freshwater localities far inland. There are no records of this species north of the mouth of the St. Johns River, indicating that this is the northern boundary of its range on the Atlantic coast. A freshwater population of *S. scovelli* is also found in the Santa Fe River System, a major tributary of the Suwannee River, in the central part of the upper peninsula of Florida (Hellier, 1967). Gunter (1942) reported that *S. scovelli* inhabits most of peninsular Florida; however, known freshwater records of *S. scovelli* in Florida are limited to the St. Johns and Santa Fe rivers. Elsewhere, a breeding population in fresh water is known from Lake St. John, Louisiana, which is over 300 miles inland (Whatley, 1962, 1969).

S. floridae ranges from Chesapeake Bay and Bermuda through the Bahamas to the southern Florida Atlantic coast and the Florida Keys, along the west coast of Florida and throughout the northern Gulf of Mexico, and in the western Gulf of Mexico southward to Panama. This species includes four described subspecies that present an interesting distributional pattern. The distribution of this _floridae_ complex was described by Herald (1965). _S. f. hubbsi_ ranges from Chesapeake Bay to Seabrooks Beach, South Carolina. No members of this complex occur between South Carolina and Biscayne Bay, Florida. The area from Miami south to Tortugas is inhabited by _S. f. mckayi_. _S. f. floridae_ is distributed from Cape Sable on the southwest coast of Florida to Corpus Christi, Texas. Records are scarce southward to Panama where a population meristically similar to _S. f. mckayi_ is found. Herald (1965) attributes the paucity of records in this area to limited collecting, but Gilbert and Kelso (1971) did not obtain this species in their study of the fishes in the vicinity of Tortuguero, Costa Rica. It is also apparently absent in the Gulf of Honduras (G. C. Miller, pers. comm.), which indicates that _S. floridae_ may not occur in the region between southern Texas and Panama. A large population of _S. f. nesiotes_ is present in Bermuda, but only a few specimens are recorded from the Bahamas. Only one specimen was recorded by Böhlke and Chaplin (1968) in their extensive work on the fishes of the Bahamas.

S. louisianae is a widely distributed species, although it seems to be uncommon over most of its range. Herald (1966) defined the range of this species as extending from Cape Charles, Virginia, to Florida, Texas, and Campeche, Mexico. It is known from Bermuda and Jamaica, but it is absent from the Bahamas. Böhlke and Chaplin (1968) included no records for the Bahamas. S. louisianae appears to be distributed uniformly along the Florida coast and in the northern and western Gulf of Mexico, but it is not abundant in most areas. Most museum collections of this species contain only one to a few specimens. Longley and Hildebrand (1941) included four specimens in their Tortugas collections. Springer and Woodburn (1960) took 58 specimens in Tampa Bay, and Reid (1954) recorded thirteen specimens at Cedar Key, Florida. In contrast, Joseph and Yerger (1956) stated that S. louisianae was the most commonly taken pipefish in their investigation of the fishes of Alligator Harbor on the northwestern coast of Florida, although the number collected was not given.

The diminutive pipefish, M. crinigerus, ranges from southern Florida to possibly Brazil. Herald (1966) described the range of this inshore species as extending from Miami, Florida, through the Gulf of Mexico to Cameron, Louisiana, to Yucatan and Albrohlos Island, Brazil, and through the Bahamas. Böhlke and Chaplin (1968) reported a single specimen from Hog Island on the Great Bahama Bank. Earlier Herald (1942) had indicated that the record of M. crinigerus from Albrohlos Island, Brazil, was doubtful. The distributional pattern of this species somewhat resembles that of S. scovelli; accordingly, the possibility of an antitropical distribution applies here also.

Published Florida Records

The literature was surveyed extensively for previously reported localities for species covered in this investigation. These are included in the following list of published Florida records. This list also includes general faunal works that include Florida, even though a specific locality might not have been given. Each record is represented by the author, date of publication, page number, and locality.

SYNGNATHUS SCOVELLI (EVERMANN AND KENDALL)

Siphostoma scovelli Evermann and Kendall, 1896:115 (Marco, Key West). -- Jordan and Evermann, 1896a:327 (both coasts of Florida). -- Evermann and Bean, 1898:242 (Pelican Island, Titusville, Cocoa). -- Evermann and Kendall, 1900:63 (Key West, Lake Worth, Cape Florida, Anclote Sponge Kraals, St. Johns River, Palatka, Welaka, Lake Monroe).

Syngnathus scovelli, Jordan and Thompson, 1905:235 (Tortugas). -- Fowler, 1940a:11 (Boca Grande); 1940b:238 (St. Johns River, mouth of Blue Springs Run). -- Herald, 1942:133 (Matanzas). -- Hamilton, 1942:188 (Bonita Springs). -- Gunter, 1942:311 (Florida, fresh water). -- Reid, 1954:24 (Cedar Key). -- Bailey, Winn, and Smith, 1954:146 (Escambia River). -- Kilby, 1955:227-228 (Cedar Key, Bayport). -- Joseph and Yerger, 1956:129 (Alligator Harbor). -- Briggs, 1958:267 (northeastern Florida). -- Carr and Goin, 1959:109 (St. Johns River, freshwater springs). -- Springer and Woodburn, 1960:31 (Tampa Bay). -- Tabb and

Manning, 1961:617 (Florida Bay). -- Springer and McErlean, 1962: 54 (Lower Matecumbe Key). -- Powell and Strawn, 1963:115 (Cedar Key, Tampa Bay). -- Roessler, 1965:314 (Biscayne Bay). -- Moe, Heemstra, Tyler, and Wahlquist, 1966:27 (Pinellas, Sarasota, Lee, Bay, Brevard, St. Lucie, Martin, Monroe, and St. Johns counties). -- Hellier, 1967:21-22 (Santa Fe River). -- Tagatz, 1968:38 (St. Johns River).

Syrictes scovelli, Jordan, Evermann, and Clark, 1930:242 (both coasts of Florida). -- Carr, 1936:86 (Florida, fresh water).

Siphostoma affine, Jordan and Gilbert, 1882:264 (Pensacola Bay). -- Swain, 1882:313 (Pensacola). -- Bean, 1883:430 and 457 (Pensacola, St. Johns River). -- Jordan, 1884a:45 (Egmont Key); 1884b: 114 (Key West). -- Jordan and Swain, 1884:231 (Cedar Keys). -- Swain and Meek, 1884:239 (Key West). -- Henshall, 1891:375 (Cards Sound, Barnes Sound, Key West, Marco, Big Gasparilla, Lemon Bay, Long Boat Key, Garden Key).

Siphostoma affinis, Jordan and Gilbert, 1883:383 (St. Johns River).

Syngnathus pelagicus, Fowler, 1921:443 (misidentification, Lake George).

Siphonostoma sp., Jordan, 1880:22 (St. Johns River).

SYNGNATHUS FLORIDAE (JORDAN AND GILBERT)

Siphostoma floridae Jordan and Gilbert, 1882:263-264 (type locality, Pensacola Bay). -- Swain, 1882:312-313 (Pensacola). -- Bean, 1883: 430 (Pensacola Bay). -- Jordan, 1884b:114 (Key West). -- Swain and Meek, 1884:238-239 (Key West). -- Henshall, 1891:375 (Gordon's Pass, Big Gasparilla). -- Evermann and Kendall, 1900:63 (Key West, Anclote Sponge Kraals, Cape Florida). -- Borodin, 1928:16 (Florida).

Syngnathus floridae, Longley and Hildebrand, 1941:63-64 (Tortugas). -- Herald, 1942:133 (Pensacola). -- Manter, 1947:375 (Tortugas). -- Reid, 1954:26-27 (Cedar Key). -- Joseph and Yerger, 1956:129-130 (Alligator Harbor). -- Springer and Woodburn, 1960:31-32 (Tampa Bay). -- Tabb and Manning, 1961:617 (Florida Bay). -- Springer and McErlean, 1962:54 (Lower Matecumbe Key). -- Roessler, 1965: 314 (Biscayne Bay). -- Moe, Heemstra, Tyler, and Wahlquist, 1966: 25-26 (Pinellas, Pasco, and Martin counties).

Syngnathus floridae floridae, Kilby, 1955:228 (Cedar Key). -- Briggs, 1958:267 (northern Gulf coast of Florida). -- Herald, 1965:367-370 (Cape Sable, Pensacola).

Syngnathus floridae mackayi, Briggs, 1958:267 (southern Florida, Florida Keys).

Syngnathus floridae mckayi, Herald, 1965:367 (Miami, Key West, Tortugas).

Syngnathus floridae subsp., Briggs, 1958:267 (eastern Gulf of Mexico along the Florida mainland).

Siphostoma mckayi Swain and Meek, 1884:239 (type locality, Key West).

Siphostoma mackayi, Jordan, 1884b:115 (Key West). -- Jordan and Evermann, 1896a:326 (Key West); 1896b:766 (Key West, Snapper Banks off Pensacola). -- Jordan, 1886:225 (Pensacola). -- Evermann and Kendall, 1900:62 (Cape Florida, Key West, Anclote Sponge Kraals).

Syngnathus mackayi, Jordan and Thompson, 1905:235 (Tortugas). --

Fowler, 1906:93 (Marquesas Key, Big Pine Key); 1921:443 (Marquesas Key, Big Pine Key); 1926:250 (Boca Grande). -- Breder, 1925:23 (Loggerhead Key, Alligator Light Reef). -- Jordan, Evermann, and Clark, 1930:241 (Key West). -- Fowler, 1940a:11 (Boca Grande); 1941:84 (Sanibel, Boca Chica). -- Moe, Heemstra, Tyler, and Wahlquist, 1966:27 (Monroe County).

Syngnathus mackayi mackayi, Herald, 1942:133 (Key West, Dry Tortugas).

SYNGNATHUS LOUISIANAE GÜNTHER

Syngnathus louisianae, Goode and Bean, 1880:333-334 (San Marco Island). -- Fowler, 1906:94-95 (Marquesas Key, Big Pine Key, Hailer's Rock); 1915:248 (Palm Beach); 1921:444 (Marquesas Key, Big Pine Key, Hailer's Rock, West Palm Beach); 1940a:11 (Boca Grande); 1941:84 (Sanibel). -- Longley and Hildebrand, 1941:64-65 (Tortugas). -- Fowler, 1945:285 (Lemon Bay, Key West, Port Everglades). -- Reid, 1954:25-26 (Cedar Key). -- Kilby, 1955:228 (Cedar Key). -- Joseph and Yerger, 1956:129 (Alligator Harbor). -- Briggs, 1958:267 (Florida). -- Springer and Woodburn, 1960:32 (Tampa Bay). -- Springer and McErlean, 1962:54 (Lower Matecumbe Key). -- Powell and Strawn, 1963:115-116 (Cedar Key, Tampa Bay). -- Moe, Heemstra, Tyler, and Wahlquist, 1966:26 (Martin, Pinellas, Sarasota, Brevard, and Monroe counties). -- Tagatz, 1968:38 (St. Johns River).

Siphostoma louisianae, Jordan, 1884b:114 (Key West). -- Swain and Meek, 1884:239 (Key West). -- Henshall, 1891:375 (Egmont Key). -- Jordan and Evermann, 1896a:327 (Key West); 1896b:770 (Key West). -- Evermann and Bean, 1898:242 (Titusville, Cocoa). --

Evermann and Kendall, 1900:63 (Cape Florida, Anclote Sponge Kraals, Tampa Bay).

Syrictes louisianae, Jordan, Evermann, and Clark. 1930:242 (Key West).

MICROGNATHUS CRINIGERUS (BEAN AND DRESEL)

Siphostoma crinigerum Bean and Dresel, 1884:99 (type locality, Pensacola). -- Jordan, 1884b:115 (Key West). -- Swain and Meek, 1884: 239 (Key West). -- Jordan and Evermann, 1896a:328 (Pensacola, Key West); 1896b:771-772 (Pensacola, Key West).

Micrognathus crinigerus, Herald, 1942:134 (Miami). -- Reid, 1954:27 (Cedar Key). -- Joseph and Yerger, 1956:130 (Alligator Harbor). -- Briggs, 1958: 267 (southern Florida). -- Springer and Woodburn, 1960:33 (Tampa Bay). -- Springer and McErlean, 1962:48 (Lower Matecumbe Key). -- Powell and Strawn, 1963:112 (Cedar Key, Tampa Bay). -- Moe, Heemstra, Tyler, and Walquist, 1966:25 (Pinellas, Monroe, and Hernando counties).

Micrognathus criniger, Fowler, 1945:286 (Lemon Bay, Key Largo, Sanibel, Boca Raton).

Micrognathus crinigera, Kilby, 1955:228 (Cedar Key).

Syngnathus crinigerum, Jordan, Evermann, and Clark, 1930:241 (Pensacola, Key West).

Anarchopterus criniger, Hubbs, 1935:3 (Lemon Bay). -- Fowler, 1941:84 (Sanibel).

Simosyngnathus criniger, Fowler, 1940a:12 (Boca Grande).

Micrognathus jonesi, Fowler, 1921:442 (Anclote Bay, Point Pinellas).

Material Examined

Museum collections from various localities through the ranges of these four species in Florida were examined in the course of the study. These collections are listed below. Abbreviations used to designate collections are as follows: UF-- University of Florida, FSU--Florida State University, UMML--Rosenstiel School of Marine and Atmospheric Sciences, University of Miami, and TABL--Tropical Atlantic Biological Laboratory. Each collection is represented by the locality, catalog number, and number of specimens.

Syngnathus scovelli (Evermann and Kendall)

Volusia County: Lake Beresford, 4.1 mi. S.W. of Deland, UF 6828 (8).

Marion County: Salt Springs, UF 6816 (1); UF 6817 (5).

Putnam County: Johns Landing, Little Lake George, UF 6784 (6); UF 6787 (4); UF 6792 (5); UF 6793 (6), UF 6794 (4); UF 6788 (7); UF 6780 (3); UF 6791 (3); UF 6781 (1); UF 6789 (20); UF 6782 (11); UF 6790 (6); UF 6785 (17); UF 6779 (2); UF 6786 (1); Orange Point, Little Lake George, UF 6802 (1); UF 6795 (4); UF 6796 (9); UF 6800 (6); UF 6801 (4); UF 6804 (5); UF 6798 (61); UF 6803 (3); UF 6807 (22); UF 6805 (2); UF 6797 (21); UF 6806 (9); Croaker Hole Cove, Little Lake George, UF 6809 (5); UF 6810 (2); UF 6808 (9); N. side of E. fill at highway bridge at Palatka, UF 6812 (2); UF 6813 (4); St. Johns River near shad hatchery dock, Welaka, UF 6829 (2); St. Johns River at Welaka, UF 6830 (16); Jenerson Point 2 mi. S. of Welaka in St. Johns

River, UF 6820 (3); St. Johns River at Turkey Island, 2 mi. N. of Welaka, UF 6831 (2); St. Johns River at Mt. Royal Ferry, UF 6826 (1); N.W. shore of Drayton Island opposite Georgetown, UF 6814 (16).

Clay County: Doctor's Inlet and Lake, UF 6827 (2); UF 6823 (12); Doctor's Lake near Orange Park, UF 6832 (3); Doctor's Inlet, 1 mi. S. of Orange Park, UF 6822 (6); St. Johns River at Green Cove Springs, UF 16794 (3).

Duval County: Trout River at Jacksonville, St. Johns River System, UF 16853 (2); Dunn Creek near its confluence with St. Johns River, N.E. of Jacksonville, UF 16867 (2); San Carlos Creek near New Berlin, UF 6818 (2); Clapboard Creek near St. Johns River, N.E. of Jacksonville, UF 16739 (1); Dunn Creek near St. Johns River, E. of Jacksonville, UF 16756 (2).

Brevard County: Indian River Lagoon, near Dummit Grove, just off St. Hwy A1A ca. 9 mi. N.E. of Titusville, UF 9702 (6); Indian River 4.7 AL mi. E. of Titusville, UF 9709 (8); Indian River on N. Merritt Island, N.E. of Titusville, just off St. Hwy 402, UF 9684 (17); Indian River, 1/4 mi. E. of Titusville along causeway, UF 837 (4); Indian River, W. Bank, 2.5 mi. N. of Mims, UF 3485 (5); Indian River at Melbourne, UF 6821 (25).

Indian River County: Atlantic Ocean Beach at Vero Beach and points several mi. S. of Sebastian Inlet, UF 12023 (1).

Martin County: Sewalls Point, UF 4796 (3); UF 4814 (5); Indian River, W. Bank at Eden, UF 4788 (9); Indian River at Jensen Beach, UF 4375 (2).

Dade County: Bear Cut at Virginia Key, grass flats at Marine Laboratory, UMML 3560 (10); UMML 3558 (24); Biscayne Bay, marker 3, UMML 14199 (1); Virginia Key, UMML 8185 (15).

Monroe County: N.E. side Little Torch Key, facing garbage on Big Pine, UF 8671 (1); Large bay on Atlantic side of Key Largo, midway of key side, UF 8673 (2); West end of Spanish Harbor Key at U.S. 1, UF 7075 (4); Off Woman Key, UF 4162 (2); Quarry on Crawl Key, ca. 9 mi. N.E. of Marathon on U.S. Hwy 1, UF 10961 (4); Upper end of Little Torch Key, beside U.S. Hwy 1 bridge, UF 11721 (25); Everglades National Park, Clearwater T-1, UMML 8398 (2); Everglades National Park, Joe Kemp Channel S. of Flamingo, UMML 8374 (11); Everglades National Park, Joe Kemp Channel T1-6, UMML 8920 (3); Everglades National Park, Joe Kemp Channel T2, UMML 13589 (1); Everglades National Park, Buttonwood Canal, UMML 15825 (1); Everglades National Park, Flamingo, UMML 15452 (2); Everglades National Park, Clearwater Pass and Oyster Bay (Western Whitewater Bay), UMML 12338 (21).

Collier County: 1 mi. S. of Everglades on Fla. 29, UMML 8799 (18); Bonita Springs Beach, UMML 5565 (2).

Lee County: Bonita Beach, Estero Bay, UF 3430 (27); Bonita Springs Beach, UMML 9590 (1); Estero Island, Beach Gulf side, UF 3443 (1).

Charlotte County: In rocks on E. side of N. end of RR trestle to Gasparilla Island from mainland, Gasparilla Sound, UF 12324 (15).

Pinellas County: Tampa Bay, S.W. end of Gandy Bridge, FSU 10 (94); Pass-A-Grille, N. end of Pine Island, FSU 8 (47); Pass-A-Grille,

W. of Pine Key, FSU 7 (64); FSU 9 (22); Pass-A-Grille, W. side of Pine Island, S.E. of red light, FSU 11 (17).

Levy County: Cedar Keys, Rum Key flat, UF 2744 (16); Cedar Keys, shallow flats near Seahorse Key, UF 3341 (10); Deep Creek, 3 mi. E. of Cedar Key, UF 1470 (5).

Gilchrist County: Blue Springs, UF 6811 (2).

Suwannee County: Ichetucknee Spring, UF 4670 (2); UF 9573 (1).

Columbia County: Ichetucknee Spring, UF 6824 (1); UF 6825 (1); Hole in Santa Fe River, 1.5 mi. above Ichetucknee Run, UF 8538 (3); Santa Fe River at Duncan's Landing, UF 8172 (1); UF 8532 (28).

Wakulla County: Grass and sand flats within 2 mi. radius of Spring Creek, FSU 14637 (27); Small tidal slough on Ochlockonee River, 4.4 mi upstream from Ochlockonee Bay FSU 16167 (5); Ochlockonee River, 3.1 mi. upstream from Ochlockonee Bay, FSU 16009 (2).

Franklin County: Alligator Harbor, off Camp Weed, 1.5 mi. S.E. of St. Teresa, FSU 1912 (5); Alligator Harbor, sand bar at mouth of Harbor, FSU 1093 (5); Gulf beach on Alligator Penninsula, 1 mi. W. of Bald Point, FSU 2077 (42).

Bay County: St. Andrews Bay, grass flats at Wayside Park, N. of Hathaway Bridge, FSU 17241 (19).

Okaloosa County: Santa Rosa Sound, 1 mi. W. of Fort Walton, FSU 2043 (28).

Escambia County: N. end of bridge to Pensacola Beach, W. side of bridge, FSU 13 (52); N. shore of Santa Rosa Sound, at S.E. edge of Pensacola, 1 mi. W. Hwy 98 Bridge, FSU 14165 (4).

Syngnathus floridae (Jordan and Gilbert)

Dade County: Virginia Key at Bear Cut, UMML 106 (1); UMML 5481 (3); UMML 1688 (4); UMML 1063 (3); Biscayne Bay at marker 28, UMML 14220 (1); Biscayne Bay at Bear Cut, UMML 1130 (1); Biscayne Bay, across bridge from University of Miami Marine Laboratory, Key Biscayne, UF 10365 (4); Virginia Key, N.E. side at ocean, UMML 8327 (9); Biscayne Bay at marker 3, UMML 13954 (3); UMML 13953 (4).

Monroe County: Barnes Sound, approximately 1 mi. off shore of mainland, FSU 8136 (1); Key Largo, UF 1255 (2); Plantation Key, midway of island, south coast, UF 12629 (1); N.E. side Little Torch Key facing garbage, UF 8667 (1); Dry Tortugas, Garden Key, UF 4155 (2); Everglades National Park, Sandy Key Basin, UMML 8089 (4); UMML 8196 (2); Everglades National Park, Joe Kemp Channel T2, UMML 13591 (4); UMML 10295 (3); Everglades National Park, Joe Kemp Channel T1-6, UMML 8925 (9); Everglades National Park, Sandy Key Bank T2, UMML 10292 (6); Everglades National Park, Sandy Key Channel and Joe Kemp, UMML 8720 (17); Sandy Key Basin, S.W. side of Flamingo, UMML 5018 (8).

Lee County: Punta Rosa, 0.25 mi. from ferry landing at end Rt. 867, FSU 4104 (1).

Pinellas County: St. Petersburg, UF 4172 (1).

Franklin County: Alligator Harbor, sand bar, mouth of harbor, FSU 1092 (6); Gulf of Mexico, Dog Island Reef E. of Carrabelle (84° 27' W., 29° 51' N.), FSU 13430 (2); Sand bar between Alligator Point and St. Teresa, FSU 2059 (33); FSU 1667 (76).

Escambia County: N. shore of Santa Rosa Sound, on S.E. edge of

Pensacola, 1 mi. W. Hwy 98 Bridge, FSU 14164 (4).

Syngnathus louisianae Günther

Duval County: Dunn Creek near St. Johns River, E. of Jacksonville, UF 16812 (2); UF 16755 (1); Jetties off St. Johns River, UF 16800 (1); San Carlos Creek just N. of New Berlin, UF 6778 (2); Clapboard Creek near St. Johns River, N.E. of Jacksonville, UF 16738 (1); Trout River at Jacksonville, UF 16743 (1); San Carlos Creek, near New Berlin, UF 6777 (5).

Brevard County: Indian River Lagoon, near Dummit Grove, just off St. Hwy A1A, ca. 9 mi. N.E. of Titusville, UF 9696 (1); Merritt Island, Banana River, E. end of barge canal, Cocoa, UMML 1658 (5); Banana River, E. end of barge canal, Merritt Island, UMML 3313 (1); Banana Creek, at Hwy A1A, N.W. side, Canaveral Station 8, TABL uncataloged (1).

Martin County: Intracoastal waterway, 2.5 mi. N. Jupiter Inlet, FSU 12862 (9); FSU 11902 (24); FSU 12791 (9); FSU 12917 (15); FSU 11457 (9); Indian River, Hutchinson Island at old Coast Guard Station, UF 4695 (1); Indian River at Jensen Beach, UF 4381 (5).

Palm Beach County: Loxahatchee River, 2 mi. W. of Jupiter Inlet, South Inlet, FSU 9993 (2).

Dade County: Virginia Key, UMML 8195 (1); UMML 8187 (14); Virginia Key at Bear Cut, UMML 4002 (1); UMML 3554 (5); UMML 8248 (2); Virginia Key at Bear Cut and #2 bridge Rickenbacker Causeway, UMML 906 (7); Miami, Coconut Grove, Biscayne Bay, UMML 3968 (1); Key Biscayne, S.W. end in boat basin at Matheson Estate, UMML

1948 (1); Biscayne Bay, marker 28, UMML 13949 (1); Bear Cut, Key Biscayne, Station 67-73, TABL uncataloged (2); Seaquarium mudflats, Virginia Key, Station 67-197, TABL uncataloged (2); TABL basin, Virginia Key, A-2, TABL uncataloged (1); Seaquarium mudflats, Virginia Key, Station 67-48, TABL uncataloged (2); Seaquarium mudflats, Virginia Key, Station 68-5, TABL uncataloged (1); TABL basin, Virginia Key, P-12, TABL uncataloged (1); Seaquarium by wall, Virginia Key, D-26, TABL uncataloged (2); Bear Cut, Key Biscayne, Station 67-293, TABL uncataloged (1); Seaquarium by wall, Virginia Key, D-32, TABL uncataloged (1); Seaquarium by wall, Virginia Key, D-1, TABL uncataloged (1); Seaquarium mudflats, Virginia Key, Station 67-268, TABL uncataloged (3); Seaquarium by wall, Virginia Key, D-24, TABL uncataloged (1); Bear Cut, Key Biscayne, Station 67-281, TABL uncataloged (1); Bear Cut, Key Biscayne, Station 67-221, TABL uncataloged (1).

Monroe County: Everglades National Park, Buttonwood Canal Bridge, UMML 15717 (1); UMML 15441 (1); Upper end of Little Torch Key, beside U.S. Hwy 1 Bridge, UMML 11718 (2); Couchie Channel off Cape Sable, in eel grass beds, UMML 5011 (3); 200 yards N.N.W. of Alligator Light, UMML 18715 (1); Everglades National Park, Joe Kemp T-1,2,3, UMML 8406 (1); Everglades National Park, Joe Kemp Channel S. of Flamingo, UMML 8375 (1); Patch Reef, 0.25 mi. N.W. of Alligator Light, UMML 18309 (1).

Collier County: Marco Island, N. of jct. of Florida Rt. 29 and beach, UMML 3705 (1).

Lee County: Bonita Springs Beach, UMML 9589 (1); UMML 2344 (3);

Bonita Springs Beach, N. of public beach, UMML 8213 (3); Bonita Springs Beach, 0.5 mi. N. of public beach, UMML 4750 (4); Bonita Beach, Estero Bay, near S. end, UF 3431 (1); Big Pine Island at Bookeelia, UMML 7998 (1).

Charlotte County: Slough on N. end of Gasparilla Island, Gulf side, UF 9152 (1); Bird Key and beaches along fill for bridge approach just W. of Gasparilla, Gasparilla Sound, UF 9151 (1).

Levy County: Cedar Keys, beach at airstrip, UF 2723 (2); Cedar Keys, main ship channel, outside Seahorse Key, UF 3171 (1); Cedar Keys, sand spot, UF 1439 (1); Cedar Keys, flats N. side of Atsena Otie, UF 2724 (3); Cedar Key, R-XII-1050-1, UF uncataloged (1); Cedar Key, R-X-850-4, UF uncataloged (1); Cedar Key, R-V-851-1, UF uncataloged (1); Cedar Key, R-V-1550-4, UF uncataloged (1); Cedar Key, R-VIII-2650-3, UF uncataloged (1).

Wakulla County: Within 2 mi. radius of Spring Creek, FSU 14636 (1).

Franklin County: South shore Ochlockonee Bay, by bridge, on Rts. 30 and 319, FSU 466 (3); Alligator Harbor, FSU 4652 (1); Open coast, 1.5 mi. S.E. of mouth of Ochlockonee River, FSU 13896 (1); St. George Sound between Carrabelle and Lanark, FSU 10939 (2).

Straits of Florida: 25°36.3' N., 80°03.6' W., TABL 102114 (1).

Micrognathus crinigerus (Bean and Dresel)

Dade County: Bear Cut at Virginia Key, UMML 3555 (1); UMML 8250 (1); Virginia Key, N.E. side at ocean, UMML 8338 (1); UMML 8849 (1); Boca Chita Pass, UMML 11925 (1); Biscayne Bay at Matheson Hammock, UMML 2727 (2); Key Biscayne at Bear Cut and Atlantic Ocean, UMML

4193 (2).

Monroe County: Sugarloaf Key, S. of U.S. 1 on secondary road, UMML 5142 (5); Florida Bay side of Long Key, 3.3 mi. S.W. of Greyhound Key, UMML 4812 (1); W. side Largo Sound, Key Largo, UMML 79 (3); UMML 4623 (3); 24°38'18" N., 81°34'30" W., Key just S. of Lower Sugarloaf viaduct on the ocean side, UMML 1243 (4); Barnes Sound, 1.5 mi. N. of Jewfish Creek on U.S. #1, UMML 3129 (15); 2.5 mi. N.N.E. of Alligator Light, UMML 19614 (3); Key Largo, UF 1253 (3); Upper end of Little Torch Key, beside U.S. Hwy 1, UF 11719 (1); Quarry on Crawl Key, ca. 9 mi. N.E. of Marathon, on U.S. Hwy 1, UF 10960 (3); Content Key, at rock ledge, UMML 17120 (10).

Pinellas County: Tampa Bay, Big Island Bayou, UMML 1489 (2).

Levy County: Cedar Keys, Rum Key Flat, UF 2722 (1); UF 2721 (2); Cedar Keys, flats and channels around Seahorse, UF 8647 (1); Cedar Keys, Atsena Otie and Snake keys, UF 2720 (35); Cedar Keys, edge of main channel, UF 3401 (4); Cedar Keys, beach at airstrip, UF 2719 (1); Flat N. side main channel, 0.5 mi. E. of Seahorse Key, UF 8633 (1); North Key, 3 5/8 mi. N.W. of Cedar Keys, UF 6834 (16); Atsena Otie and Snake keys, R-II-551-6, UF uncataloged (1); Atsena Otie shallow flat, R-I-151-2, UF uncataloged (1); Rum Key, R-XI-750-2, UF uncataloged (1); Rum Key Flat, R-I-651-2, UF uncataloged (1); Piney Point channel, R-II-551-1, UF uncataloged (1).

MORPHOLOGICAL VARIATION

Generally, morphological variation in American pipefishes has received little attention. A detailed study of an American Pacific species, *Syngnathus californiensis*, was made by Herald (1941), and Joseph (1957) examined variation in *S. scovelli*. Intraspecific variation has not been investigated in other species.

In this study morphological variation of *S. floridae*, *S. louisianae*, and *M. crinigerus* was examined on a limited basis, but *S. scovelli* was investigated in detail for the purpose of determining if variational trends noted in this species might apply to the other species. This aspect of the study was limited to Florida populations because this is basically an ecological study with main interests lying in the interrelationships of environmental factors and morphology. Counts and measurements were made on specimens from various localities. These follow techniques described by Herald (1942, 1966) and are explained in the following paragraph.

Standard length extends from the tip of the snout with the mouth closed to the posterior edge of the hypural plate. Trunk length is the distance from the tip of the snout to the anterior origin of the anal fin; tail length then extends from the anterior origin of the anal fin to the posterior edge of the hypural plate. Predorsal length is measured from the tip of the snout to the anterior origin of the dorsal fin. The length of the dorsal fin is the distance between the most anterior and most posterior dorsal fin rays. Head length is the distance from the tip of the snout to the posterior edge of the opercular bone; snout length is similarly measured to the anterior edge of the orbit. Trunk ring counts include all body rings from the first ring containing the pectoral fin to the ring bearing the anus. Body rings posterior to trunk rings are included in tail ring counts. The last tail ring lies just anterior to the hypural ring. All dorsal and pectoral rays are included in dorsal and pectoral fin-ray counts. Pectoral fin-ray counts were made on the right pectoral fin. The position of the dorsal fin is indicated by the number of trunk and tail rings lying under it, and brood pouch position is indicated by the number of tail rings covered by it.

Standard length was measured to the nearest 0.5 mm. Other measurements were taken with dividers and estimated to the nearest 0.1 mm.

Descriptions

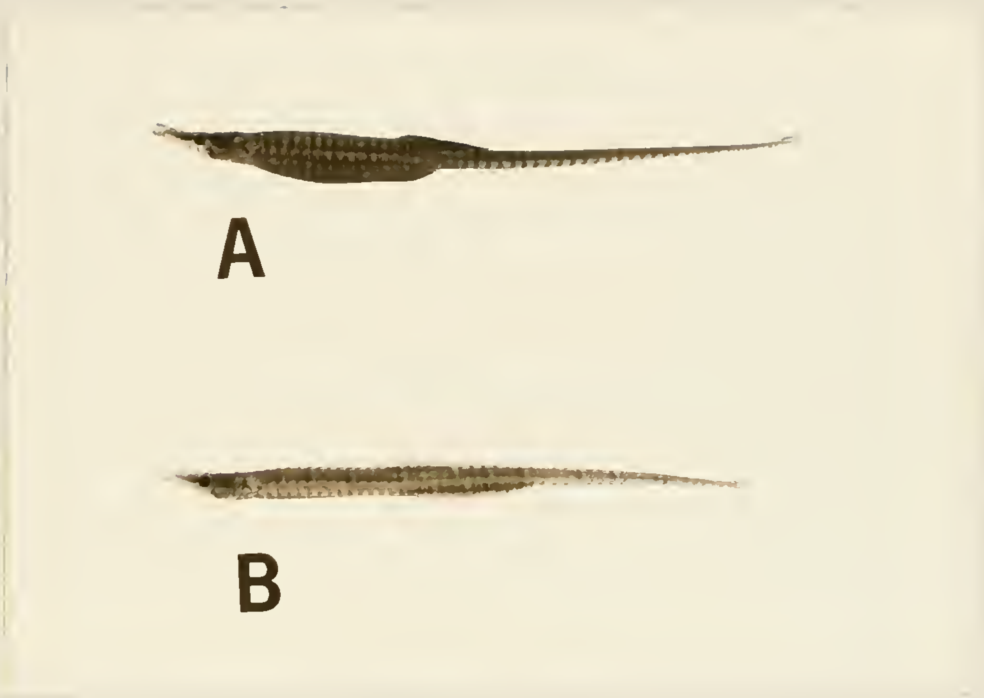
Members of the family Syngnathidae are well known because of their unusual anatomical features. These fishes are covered with an armor of bony plates. The snout is tubular with a small toothless mouth located at its anterior end. Gill membranes are broadly joined to the isthmus, restricting the gill opening to a small lateral opening just in front of the pectoral fin. Pelvic fins are totally lacking in this group. Pipefishes are usually distinguished from the seahorses by the presence of a distinct caudal fin on a tail that is not prehensile and the axis of the head lying in line with the axis of the body; however, some intermediate pipehorses, such as *Amphelikturus dendriticus*, exhibit a prehensile tail (Herald, 1959). Adult males of this family possess a brood pouch on the ventral side of either the abdomen or tail. The brood pouch is located on the underside of the tail in the species under investigation.

S. scovelli is a medium-sized pipefish with a short snout (Figure 2). Maximum standard length is 162 mm. Counts and measurements are as follows: trunk rings 15 to 17, usually 16 to 17; tail rings 29 to 35, usually 31 to 33; pectoral fin rays 10 to 16, usually 13 to 15; dorsal fin rays 27 to 36, usually 28 to 33; dorsal fin over 2 to 5 (usually 3 to 4) trunk rings and 3 to 6 (usually 4 to 5) tail rings; brood pouch over 9 to 14 (usually 11 to 13) tail rings; trunk length, head length, and snout length variable; trunk length 2.1 to 2.5 in standard length; predorsal length 2.4 to 3.0 in standard length; snout length 1.7 to 2.5 in head length. *S. scovelli* is one of the V-bellied pipefishes. This character is especially apparent in the larger females.

Living *S. scovelli* vary from dark green to dark brown in color, whereas preserved specimens are tan to dark brown in color. The short snout is mottled in color with a dark lateral band extending from the anterior edge of the eye. Regular dark bands, wider than the lighter interspaces, encircle the trunk and tail regions. Adult females also exhibit silvery V or Y-shaped marks located on the sides of each trunk ring. The deep keel of the female belly is black in color. The dorsal fin is generally translucent in color, although some females

Figure 2. *Syngnathus scovelli* from Cedar Key, Florida. A, female, 119.0 mm SL; B, gravid male, 109.0 mm SL.

Figure 3. *Syngnathus floridae* from Cedar Key, Florida. A, female, 176.5 mm SL; B, gravid male, 174.0 mm SL.


A
B

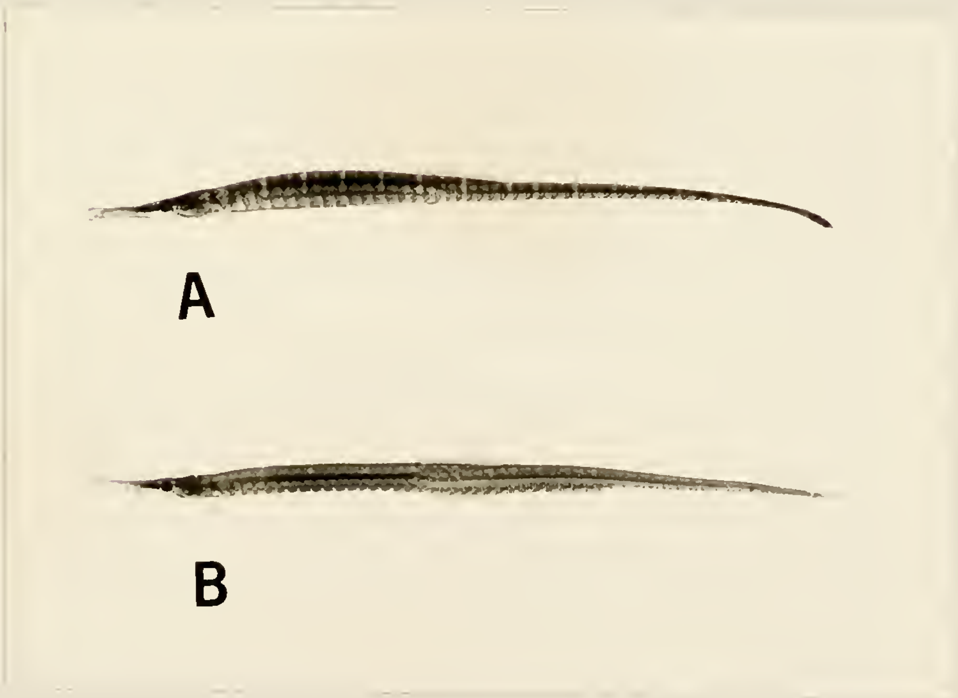

A
B

exhibit dark wavy diagonal bars on the dorsal fin. The caudal fin is dark with white spots around its margin.

S. floridae is a sizable pipefish with a long snout (Figure 3). The morphology of the various subspecies was discussed by Herald (1965). Inasmuch as counts and measurements in this study were made only on *S. f. floridae*, the present description refers only to that subspecies. *S. f. floridae* is a large subspecies, having a maximum standard length of 249 mm. Counts and measurements are as follows: trunk rings 17 to 19, usually 17 to 18; tail rings 31 to 34, usually 32 to 34; pectoral fin rays 12 to 15, usually 13 to 15; dorsal fin rays 26 to 30, usually 27 to 29; dorsal fin over 0 to 2 (usually 1) trunk rings and 5 to 6 tail rings; brood pouch over 14 to 17 (usually 14 to 16) tail rings; trunk length 2.0 to 2.2 in standard length; predorsal length 2.1 to 2.3 in standard length; head length 5.3 to 6.6 in standard length; snout length 1.6 to 1.9 in head length. *S. f. floridae* is also one of the V-bellied pipefishes, but this character is not extreme.

Coloration varies from dark green to dark brown in living *S. f. floridae*, whereas preserved specimens are tan to brown in color. The snout is mottled with a lateral dark band extending anteriorly from the orbit. There are numerous small pale spots, as well as regularly spaced dark lateral bands, wider than interspaces, along the sides of the body. Interspersed among the dark lateral bands are narrow light bands. Usually there are 4 to 5 of these bands anterior to the dorsal fin, 1 to 2 under the dorsal fin, and 5 to 7 posterior to the dorsal fin. The dorsal fin is translucent, and the darkly pigmented caudal fin is bordered by pale spots.

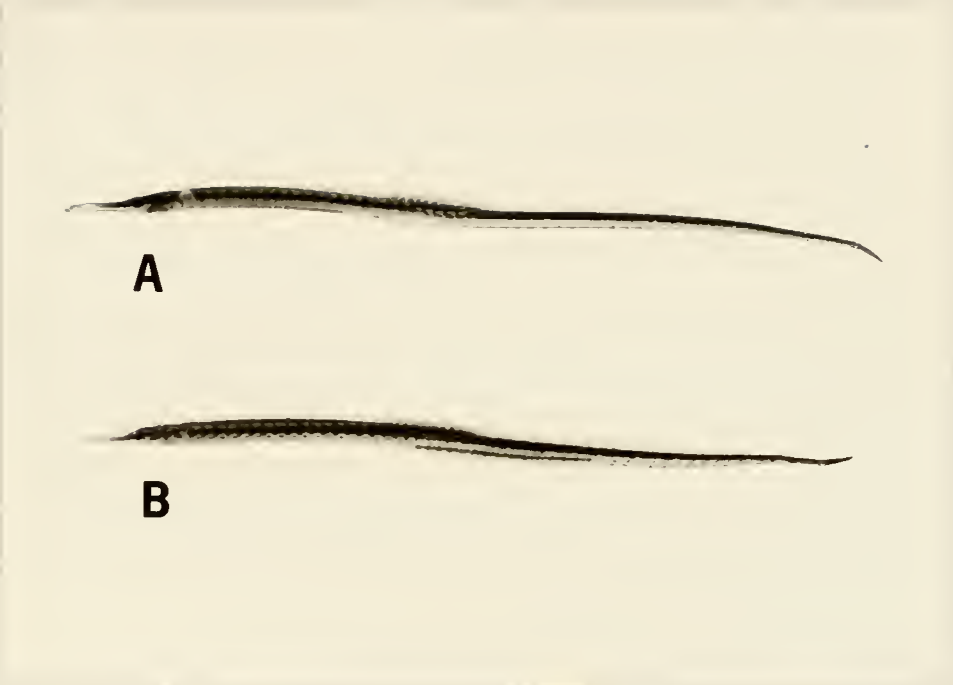
S. louisianae is one of the largest species of pipefishes (Figure 4), attaining a maximum standard length of 355 mm. Counts and measurements are as follows: trunk rings 19 to 24, usually 19 to 20; tail rings 34 to 37, usually 35 to 37; pectoral fin rays 13 to 16, usually 14 to 15; dorsal fin rays 32 to 39, usually 33 to 36; dorsal fin over 2 to 4 (usually 2 to 3) trunk rings and 4 to 5 tail rings; brood pouch over 15 to 19 tail rings; trunk length 2.1 to 2.3 in standard length; predorsal length 2.3 to 2.5 in standard length; head length 6.1 to 7.7 in standard length; snout length 1.5 to 1.8 in head length. S. louisianae is a flat-bellied pipefish.

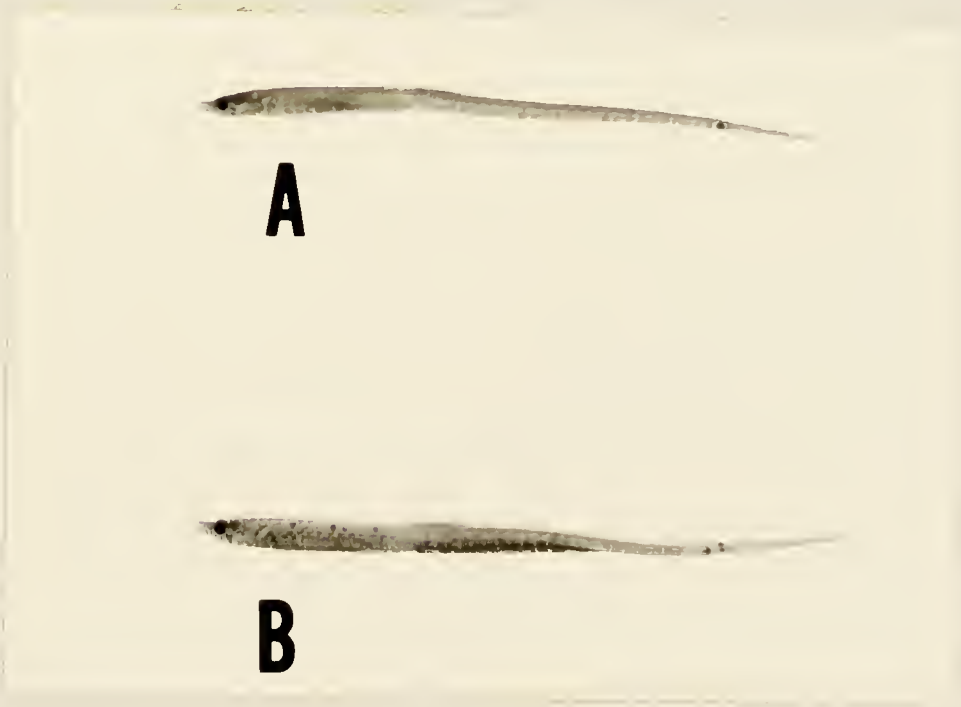
Living S. louisianae are pale brown in color, the color changing little in preservation. On the head a lateral brownish streak extends through the eye and back across the operculum. On the body narrow dark bars are found on the sides of each ring, the bars often convex on the lower surface. Frequently these form vermiculate patterns that give the appearance of a chain-like streak extending down the side of the tail. Dorsal and ventral portions of the body are largely immaculate. The base of the dorsal fin is spotted, but the rest of the dorsal fin is translucent.

The Fringed pipefish, M. crinigerus, is a diminutive species with a very short snout (Figure 5). Maximum length is 94 mm. Counts and measurements are as follows: trunk rings 15 to 17, usually 15 to 16; tail rings 32 to 39, usually 35 to 39; pectoral fin rays 7 to 10, usually 8; dorsal fin rays 16 to 20, usually 16 to 17; dorsal fin over 0 to 1 trunk rings and 3 to 4 tail rings; brood pouch over 12 to 16

Figure 4. Syngnathus louisianae. A, female, Wakulla County, Florida, FSU 14636, 244.0 mm SL; B, gravid male, Biscayne Bay, Florida, TABL uncataloged, 231.5 mm SL.

Figure 5. Micrognathus crinigerus from Cedar Key, Florida. A, female, 65.5 mm SL; B, gravid male, 69.5 mm SL.


A
B


A
B

(usually 15 to 16) tail rings; trunk length 2.5 to 3.2 in standard length; predorsal length 2.5 to 3.9 in standard length; head length 8.1 to 11.9 in standard length; snout length 2.3 to 3.3 in head length. Distinguishing characteristics of this species are the absence of an anal fin and the presence of short simple cirri on the body rings.

Living _M. crinigerus_ are nut brown in color, the color fading somewhat in preserved specimens. Head and snout are mottled in color. The body is covered with alternating dark and light bands encircling the tail and trunk. The dorsal fin is translucent.

Sexual Dimorphism

The determination of sex is quite simple in sexually mature individuals of the species under investigation. Adult males possess a brood pouch located ventrally on the tail just posterior to the anal fin. Other sexual differences in morphology may be present, but they are usually less obvious. In this study seven morphological characters were examined with respect to sexual differences. Twenty-five sexually mature males were compared with 25 sexually mature females from the same locality for the species _S. scovelli_ and _S. floridae_. Not enough sexually mature specimens of _S. louisianae_ and _M. crinigerus_ were available from the same locality for valid comparisons. Sexual maturity was determined by the presence of a fully developed brood pouch in males and the presence of developed ova in the body cavity of females.

Sexual dimorphism is very apparent in S. scovelli and has been cited by previous workers (Reid, 1954; Whatley, 1969). Some differences are so obvious they do not require quantitative treatment (Figure 2). A striking difference is found in body depth. Adult females have a much deeper trunk region than adult males, and the ventral side of the trunk region is strongly V-shaped. Herald (1942) listed this species as a member of the extreme V-bellied group. Another obvious sexual difference is the light V- or Y-shaped marks located laterally on each trunk ring of adult females. This character appears at approximately the same time sexual maturity is attained. The height of the dorsal fin is also considerably greater in adult females.

Seven morphological characters for 25 adult males and 25 adult females of S. scovelli from Cedar Key are compared by means of a t-test following procedures of Snedecor (1956) in Table 1. All 50 specimens were collected in August, 1969, which eliminates the possibility of any seasonal effects. Significant differences are present for two characters. Females tend to have a slightly longer trunk than males. This difference is reflected in their smaller tail length/trunk length ratio. Whatley (1969) obtained similar results with specimens from Lake St. John, Louisiana. Females from the Cedar Key population also tend to have a smaller dorsal fin-ray count than males. No significant differences are found among the other five characters studied.

Sexual differences are not quite so obvious in S. floridae as in S. scovelli (Figure 3). Adult females 150 mm or greater in length exhibit a greater body depth than males, but this character is

Table 1. A Statistical Comparison of 25 Adult Male with 25 Adult Female *Syngnathus scovelli* from the Cedar Key, Florida, Area with Respect to Seven Morphological Characters.

	Male		Female		
Character	Mean	Range	Mean	Range	t
Standard Length	99.7	80.1-124.0	110.9	96.9-127.1	--
Tail Length/Trunk Length	1.38	1.29-1.51	1.30	1.24-1.37	6.45*
Head Length/Snout Length	2.18	2.02-2.45	2.13	1.99-2.34	1.91
Head Length/Dorsal Length	0.99	0.89-1.10	1.01	0.91-1.11	1.46
Trunk Rings	16.0	15-16	16.0	15-16	0.00
Tail Rings	32.4	31-34	32.2	31-33	0.60
Pectoral Fin Rays	14.0	13-15	14.2	13-15	1.87
Dorsal Fin Rays	31.4	29-33	30.4	28-32	3.18*

*Significant at the 99% level.

difficult to ascertain in smaller sexually mature individuals. Females of this size are usually ripe with ova, which accounts for the increased trunk depth. The statistical analyses of the seven characters studied yielded three significant differences (Table 2). The longer trunk region of females is indicated by the smaller tail length/trunk length ratio of females. Females in the Cedar Key area also tend to have a greater head length/dorsal fin length ratio. This ratio was checked to determine which of the characters is responsible for this difference. No significant differences were found between males and females with respect to dorsal fin length, but female S. floridae from the Cedar Key population were found to have a longer head than males. Dorsal fin-ray counts in males tend to run slightly larger than in females, just as in S. scovelli.

Sexually mature individuals of S. louisianae and M. crinigerus are relatively difficult to obtain as a result of the paucity of specimens available. A statistical test for sexual differences must involve specimens from the same locality to eliminate possible geographical effects; therefore, a valid quantitative examination of sexual dimorphism in these species was impossible. If sexual differences exist, they are not apparent as are those described for S. scovelli. Adult specimens of S. louisianae and M. crinigerus are shown in Figures 4 and 5, respectively.

Georgraphical Variation

The four species of pipefishes examined in this investigation are

Table 2. A Statistical Comparison of 25 Adult Male with 25 Adult Female *Syngnathus floridae* from the Cedar Key, Florida, Area with Respect to Seven Morphological Characters.

Character	Male		Female		
	Mean	Range	Mean	Range	t
Standard Length	161.4	130.1-177.7	166.6	137.8-192.4	--
Tail Length/Trunk Length	1.13	1.05-1.21	1.06	1.00-1.12	7.61[a]
Head Length/Snout Length	1.71	1.61-1.80	1.72	1.61-1.80	0.54
Head Length/Dorsal Length	1.57	1.46-1.80	1.64	1.45-1.86	3.19[a]
Trunk Rings	17.8	17-19	17.7	17-18	1.10
Tail Rings	32.2	31-34	32.6	31-34	1.71
Pectoral Fin Rays	13.9	13-15	14.1	13-15	1.15
Dorsal Fin Rays	28.3	27-30	27.7	26-29	2.16[b]

[a] Significant at the 99% level.
[b] Significant at the 95% level.

very suitable for the study of geographical variation in morphology because they occur over a wide latitudinal and geographical range and in a variety of ecological conditions in Florida. *S. scovelli* is the most widely distributed species in the state, and its range includes both freshwater and marine habitats. For these reasons geographical variation in *S. scovelli* over its Florida range was investigated in detail. The analysis of geographical variation in *S. floridae*, *S. louisianae*, and *M. crinigerus* was limited to comparisons of 25 specimens from each of two Florida localities. These limited comparisons must be interpreted with care. Since the data represent only two localities, they can be used to suggest only the presence or absence of genuine geographical variation in morphology.

Counts and measurements of nine morphological characters were made on samples of *S. floridae* from Cedar Key and Alligator Harbor. These samples were selected so as to achieve a good mixture of sexes and sizes in order to minimize sexual and age differences. Means, ranges, and t-values are shown in Table 3. No significant differences were found between these two populations. Cedar Key and Alligator Harbor are separated by approximately 160 miles of coastline, but this separation is more on an east-west basis than on a north-south basis. Both of these localities are considered to be in the northern Gulf of Mexico, and they present similar environmental conditions. Both populations lie within the geographical range of the subspecies *S. f. floridae*; therefore, only minimal variation should be expected to occur. Morphological variation among the subspecies in the *S. floridae* complex was described by Herald (1942, 1965, 1966).

Table 3. A Statistical Comparison of 25 Specimens of *Syngnathus floridae* from Cedar Key, Florida, with 25 Specimens from Alligator Harbor, Florida, with Respect to Nine Morphological Characters. Trunk Length, Predorsal Length, Head Length, Snout Length, and Dorsal Fin Length Given as Thousandths of Standard Length.

Character	Cedar Key		Alligator Harbor		t
	Mean	Range	Mean	Range	
Standard Length	146.2	90.0-192.1	130.7	89.1-172.9	--
Trunk Length	475	453-493	472	455-492	1.25
Predorsal Length	457	442-473	458	432-477	0.21
Head Length	166	151-177	167	155-189	0.36
Snout Length	97	87-106	95	86-115	1.02
Dorsal Fin Length	102	92-112	100	90-115	1.32
Trunk Rings	17.7	17-18	17.8	17-18	0.65
Tail Rings	32.7	31-34	32.8	31-34	0.52
Pectoral Fin Rays	13.9	12-15	14.0	13-15	0.93
Dorsal Fin Rays	27.8	26-30	27.6	26-29	0.45

The comparison of populations of S. louisianae from Cedar Key and Biscayne Bay yielded several statistically significant differences (Table 4). Specimens from Biscayne Bay are inclined to have longer trunk lengths, predorsal lengths, and head lengths than specimens from Cedar Key. Trunk rings, pectoral fin rays, and dorsal fin rays are also more numerous on Biscayne Bay specimens, but Cedar Key specimens have a greater number of tail rings. Cedar Key and Biscayne Bay are separated by roughly 3.5 degrees latitude, a north-south distance of about 235 miles. Cedar Key is located at a latitude that is transitional between temperate and subtropical zones. It lies in the Gulf coastal faunal area for the marine littoral of the Florida peninsula described by Evermann and Kendall (1900). The waters of Biscayne Bay lie in a subtropical faunal area.

The greater numbers of trunk rings, pectoral fin rays, and dorsal fin rays of the Biscayne Bay specimens do not support the correlation between developmental temperature and meristic characters of fishes described by Hubbs (1922, 1926) which indicates that slower growing fishes inhabiting cooler waters develop more scales, spines, fin rays, and other elements than their faster growing counterparts in warmer waters. Martin (1949) provided evidence showing that this relationship is not consistent. Actually the reverse is true for some fishes. Any effects of temperature on morphogenetic processes apparently operate during a relatively short critical period in development. Since pipefishes in Florida usually have a long breeding season and often breed year round, any effects of temperature on meristic characters are probably obscured.

Table 4. A Statistical Comparison of 25 Specimens of *Syngnathus louisianae* from Cedar Key, Florida, with 25 Specimens from Biscayne Bay, Florida, with Respect to Nine Morphological Characters. Presentation Same as in Table 3.

	Cedar Key		Biscayne Bay		
Character	Mean	Range	Mean	Range	t
Standard Length	158.0	88.5-252.0	169.5	125.0-268.0	--
Trunk Length	452	442-471	466	441-480	6.65[a]
Predorsal Length	417	405-432	426	405-439	3.66[a]
Head Length	143	131-158	148	132-163	2.22[b]
Snout Length	90	80-100	89	73-101	0.60
Dorsal Fin Length	101	95-111	109	91-122	5.55[a]
Trunk Rings	19.8	19-21	20.1	19-21	2.19[b]
Tail Rings	36.2	35-37	35.4	34-37	3.56[a]
Pectoral Fin Rays	14.4	13-15	14.8	13-16	2.02[b]
Dorsal Fin Rays	33.8	32-35	35.0	33-37	4.52[a]

[a] Significant at the 99% level.
[b] Significant at the 95% level.

Similar results were obtained in the comparison of specimens of *M. crinigerus* from Cedar Key and the Florida Keys (Table 5). All proportional measurements, except dorsal fin length, are greater for the Florida Key population. Representatives of the Cedar Key population exhibit a greater number of tail rings. No other significant differences were found among meristic characters. *M. crinigerus* is a small species, and extreme care must be employed in taking measurements with dividers. Slight errors can have large effects upon results and may be compounded in proportional characters. The north-south separation of these two populations is only slightly greater than that described for the populations of *S. louisianae*; therefore, any effects of temperature on morphogenetic processes should be similar.

The extensive distribution of *S. scovelli* in Florida makes it an excellent species for the study of geographical variation in morphology. Its range extends considerable distances north to south on both Atlantic and Gulf coasts. In addition, freshwater populations in the St. Johns and Santa Fe rivers makes possible the study of the effects of salinity on morphological variation in this species.

Over 450 specimens, representing 12 populations scattered over the extensive range of *S. scovelli* in Florida, were examined in this part of the study. The presence of sexual dimorphism in this species has been previously demonstrated (Table 1); hence, the resulting data must be interpreted with this in mind since samples examined included adults of both sexes as well as immature individuals.

The most variable meristic character studied was the number of

Table 5. A Statistical Comparison of 25 Specimens of *Micrognathus crinigerus* from Cedar Key, Florida, with 25 Specimens from the Florida Keys with Respect to Nine Morphological Characters. Presentation Same as in Table 3.

Character	Cedar Key		Florida Keys		t
	Mean	Range	Mean	Range	
Standard Length	59.2	42.5-73.8	60.3	33.1-86.8	--
Trunk Length	334	313-366	361	341-404	6.90[a]
Predorsal Length	337	320-372	358	336-404	4.17[a]
Head Length	97	88-108	103	91-124	2.80[a]
Snout Length	35	30-41	38	30-49	2.09[b]
Dorsal Fin Length	64	53-77	67	55-86	1.67
Trunk Rings	15.5	15-17	15.8	15-17	1.58
Tail Rings	37.2	32-39	36.0	33-38	2.89[a]
Pectoral Fin Rays	8.0	7-9	8.2	8-10	1.33
Dorsal Fin Rays	16.8	16-19	17.0	16-20	0.50

[a] Significant at the 99% level.
[b] Significant at the 95% level.

dorsal fin rays. The variation in this character is illustrated in Figure 6 according to the method proposed by Hubbs and Hubbs (1954). Number of dorsal rays varies from a minimum of 27 to a maximum of 36. The lowest mean (29.4) is found in the southernmost population in the Florida Keys. Northward the mean number of dorsal fin rays tends to increase slightly in a clinal pattern, suggesting that cooler waters enhance the development of these; the pattern, however, is imperfect.

The two freshwater populations fail to indicate a relationship between salinity and the number of dorsal fin rays. The sample from the Santa Fe River population provides the highest mean (34.2) for this character, but variability in this group is small. Counts ranged from 32 to 36. The large sample from the Lake George area occupies the opposite end of the scale with the second lowest mean (29.5) encountered in this study. The brackish-water sample from Jacksonville was too small to justify the use of any parameters except mean and range. This variable sample exhibited the entire range of dorsal fin ray counts obtained for _S. scovelli_ in this study.

Tail rings, ranging from 29 to 35, demonstrated a variational pattern similar to that of dorsal fin rays (Figure 7). Generally, lower values were obtained in samples from southern Florida. The lowest mean tail ring count (31.1) was recorded from the southernmost population in the Florida Keys. Northward, values generally increased; however, the sample from the Pensacola population, with the second smallest mean (31.4), provided a noticeable exception. The Santa Fe River population again exhibited the highest mean (33.5). The mean for the Lake George population (32.5) was also sizable, suggesting

Figure 6. Distribution of dorsal fin rays in *Syngnathus scovelli*. For each sample, the horizontal line indicates the range of variation; the vertical line, the mean; the black rectangle, two standard errors of the mean on either side of the mean; the clear rectangle, one standard deviation on either side of the mean. No overlap between the black rectangles of two samples indicates a statistically significant difference between the means.

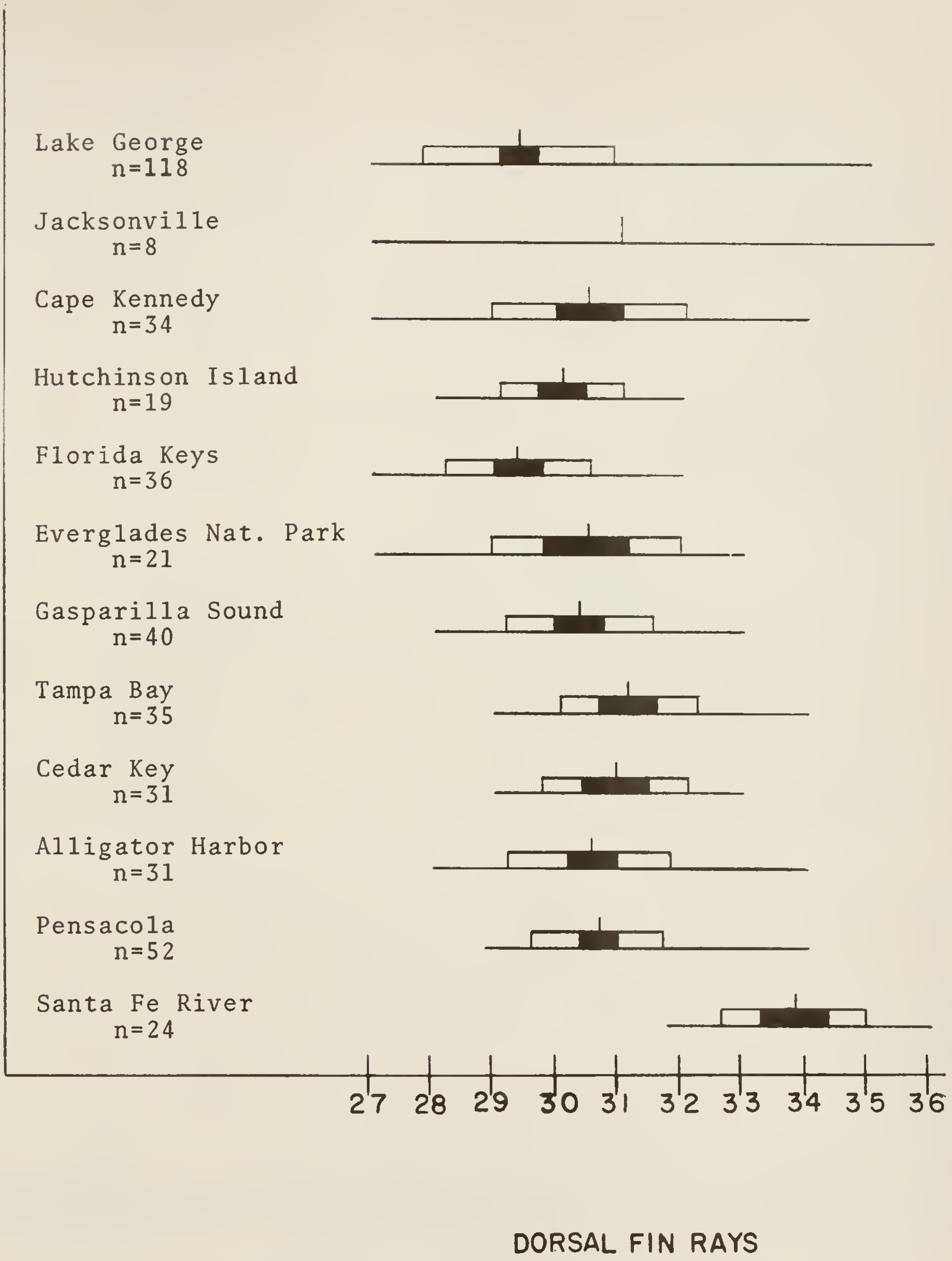
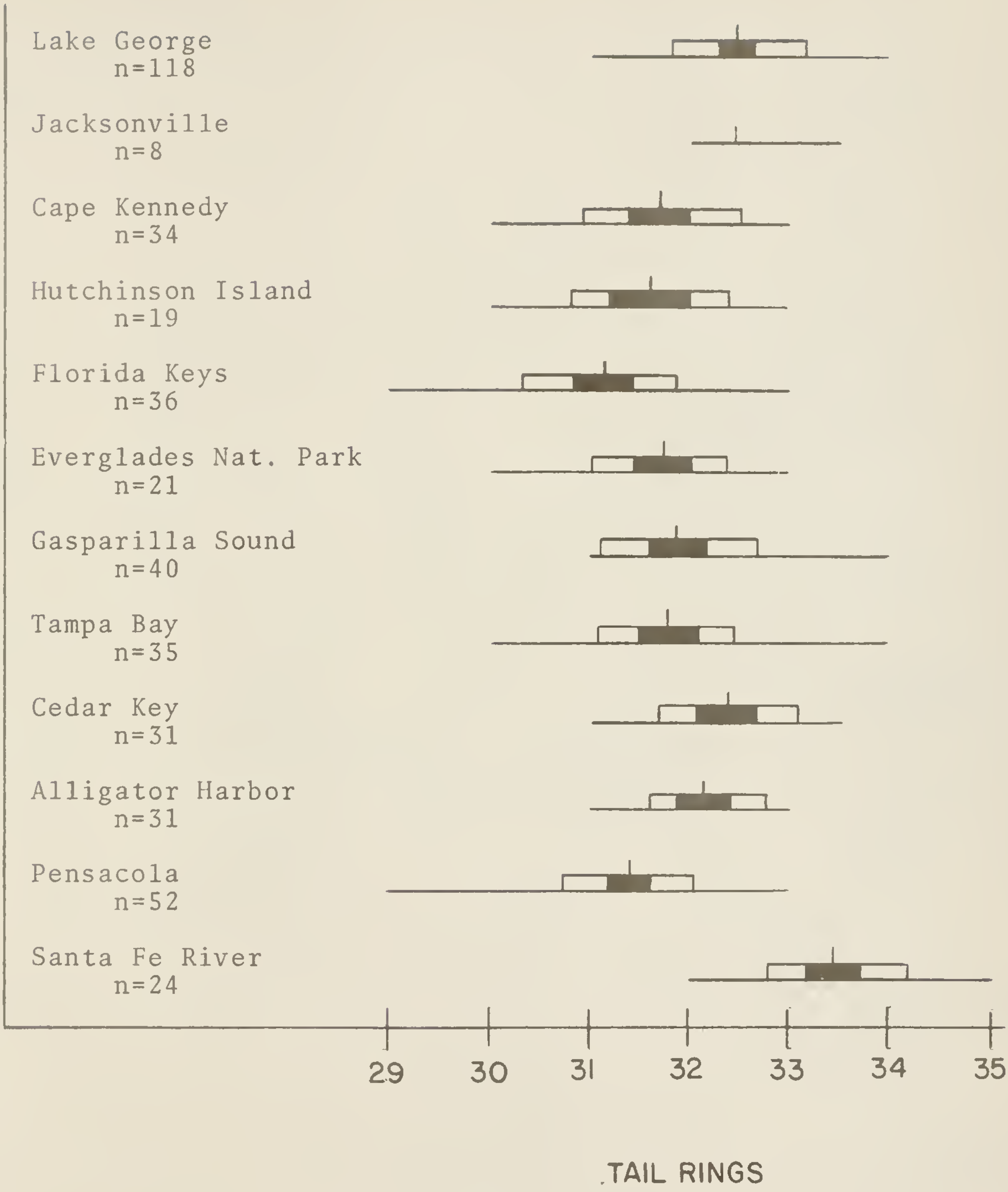

Lake George
n=118
Jacksonville
n=8
Cape Kennedy
n=34
Hutchinson Island
n=19
Florida Keys
n=36
Everglades Nat. Park
n=21
Gasparilla Sound
n=40
Tampa Bay
n=35
Cedar Key
n=31
Alligator Harbor
n=31
Pensacola
n=52
Santa Fe River
n=24
27
28
29
30
31
32
33
34
35
36
DORSAL FIN RAYS

Figure 7. Distribution of tail rings in *Syngnathus scovelli*. Presentation same as in Figure 6.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Gasparilla Sound
n=40
Tampa Bay
n=35
Cedar Key
n=31
Alligator Harbor
n=31
Pensacola
n=52
Santa Fe River
n=24
29
30
31
32
33
34
35
TAIL RINGS

that higher salinities may be correlated with increased numbers of tail rings.

The number of trunk rings and pectoral rays showed no pronounced trends in variation. Trunk rings were the most uniform character studied. A frequency distribution for this character is given in Table 6. Trunk rings varied from 15 to 17, with 16 being most common. Pectoral fin rays exhibit more variability; but again, no geographical trends are apparent (Table 7). Pectoral fin rays vary from 10 to 16, with most counts falling between 13 and 15.

Head length/snout length ratio is an important diagnostic character used to distinguish between species of pipefishes. _S. scovelli_ has a short snout, and head length is usually about twice as long as snout length. This character also presents a clinal pattern of variation (Figure 8). Head length/snout length ratio is greatest in the Florida Keys; northward, values decrease. The freshwater populations, located near the northern limit of _S. scovelli_ in Florida, correspond with this pattern and with the results of Joseph (1957) which showed that individuals from waters of low salinity have relatively longer snouts than those from waters of high salinity. Snout length is plotted against head length for the Gasparilla Sound population in Figure 9. Allometric growth is not indicated for this character.

Tail length/trunk length ratio exhibits considerable variation, but no geographical pattern is evident (Figure 10). Sexual dimorphism has been demonstrated for this character; therefore, these results may be affected by the sex ratios of the samples as much as by geographical locality. Trunk length is plotted against tail length for the

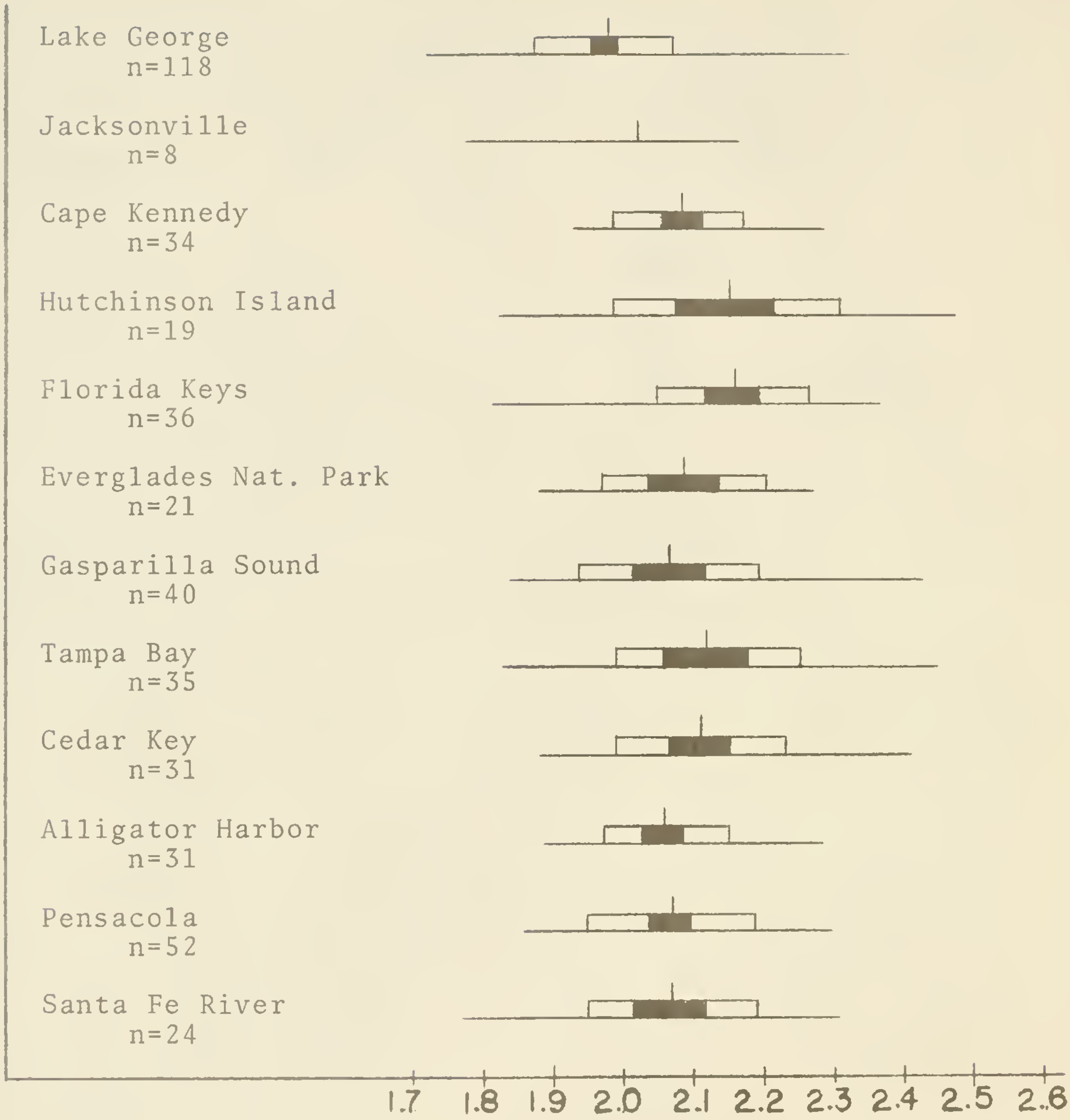
Table 6. Frequency Distribution of Trunk Rings in *Syngnathus scovelli*.

Population	Trunk Rings 15	 16	 17	No.	Mean
Lake George	3	83	22	118	16.2
Jacksonville		8		8	16.0
Cape Kennedy	4	29	1	34	15.9
Hutchinson Island	3	15	1	19	15.9
Florida Keys	1	30	5	36	16.1
Everglades National Park	4	17		21	15.8
Gasparilla Sound	5	33	2	40	15.9
Tampa Bay	1	34		35	16.0
Cedar Key		29	2	31	16.1
Alligator Harbor	1	29	1	31	16.0
Pensacola	1	47	4	52	16.1
Santa Fe River		19	5	24	16.2

Table 7. Frequency Distribution of Pectoral Fin Rays in *Syngnathus scovelli*.

Population	Number of Pectoral Fin Rays							No.	Mean
	10	11	12	13	14	15	16		
Lake George	1	1	5	27	76	8		118	13.7
Jacksonville			1	5	2			8	13.1
Cape Kennedy			1	10	21	1	1	34	13.7
Hutchinson Island			1	4	11	3		19	13.8
Florida Keys			1	11	23	1		36	13.7
Everglades National Park				2	15	4		21	14.1
Gasparilla Sound		1	1	12	22	4		40	13.7
Tampa Bay			1	5	20	9		35	14.1
Cedar Key		1		3	21	5	1	31	14.0
Alligator Harbor				7	22	2		31	13.8
Pensacola			1	17	29	4	1	52	13.8
Santa Fe River			3	12	9			24	13.3

Figure 8. Distribution of head length/snout length ratio in *Syngnathus scovelli*. Presentation same as in Figure 6.



HEAD LENGTH/SNOUT LENGTH RATIO

Figure 9. Snout length plotted against head length in *Syngnathus scovelli* from Gasparilla Sound, Florida.

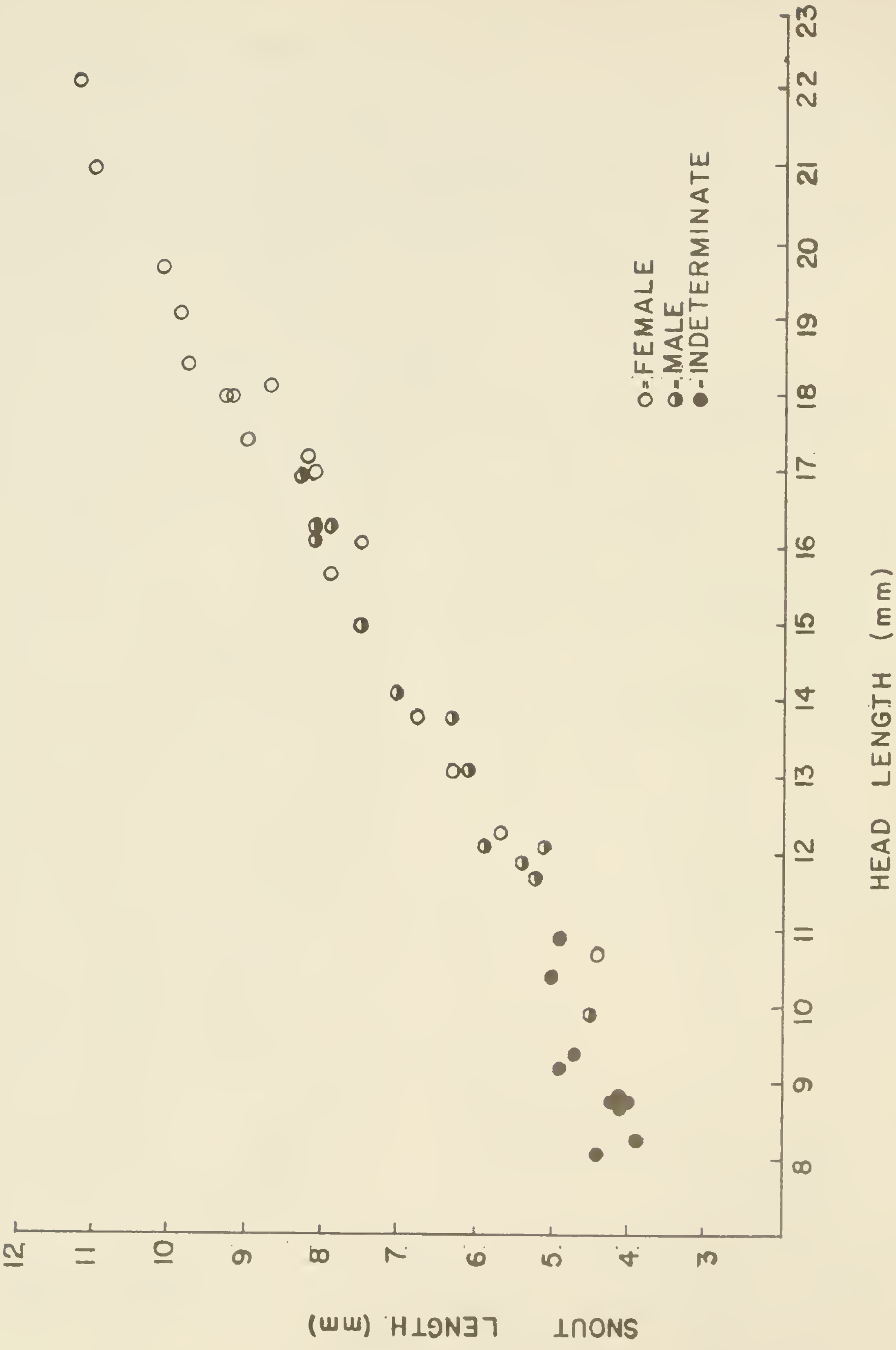
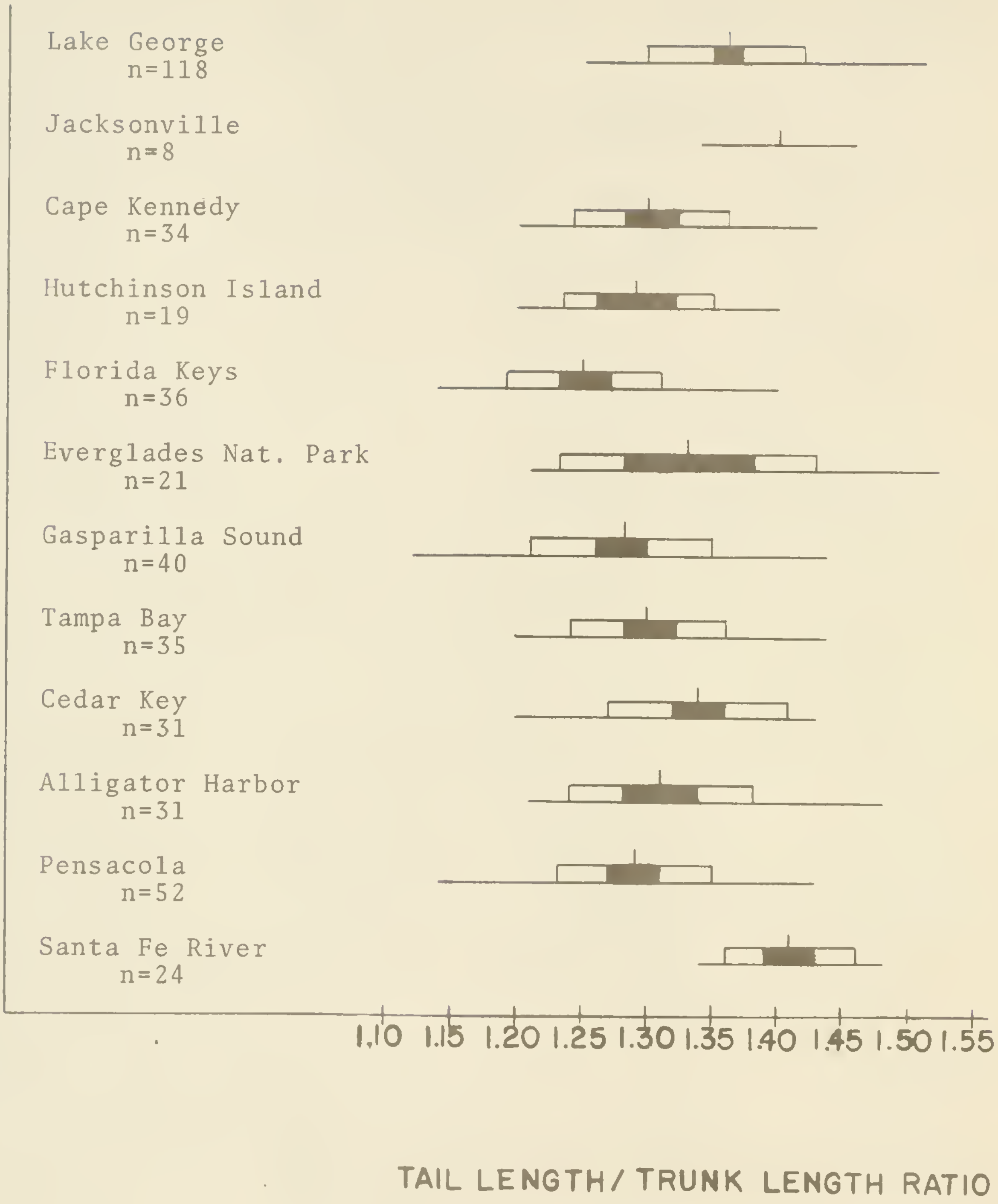

SNOUT LENGTH (mm)
3
4
5
6
7
8
9
10
11
12
HEAD LENGTH (mm)
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
○-FEMALE
◐-MALE
●-INDETERMINATE

Figure 10. Distribution of tail length/trunk length ratio in *Syngnathus scovelli*. Presentation same as in Figure 6.


Lake George
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Jacksonville
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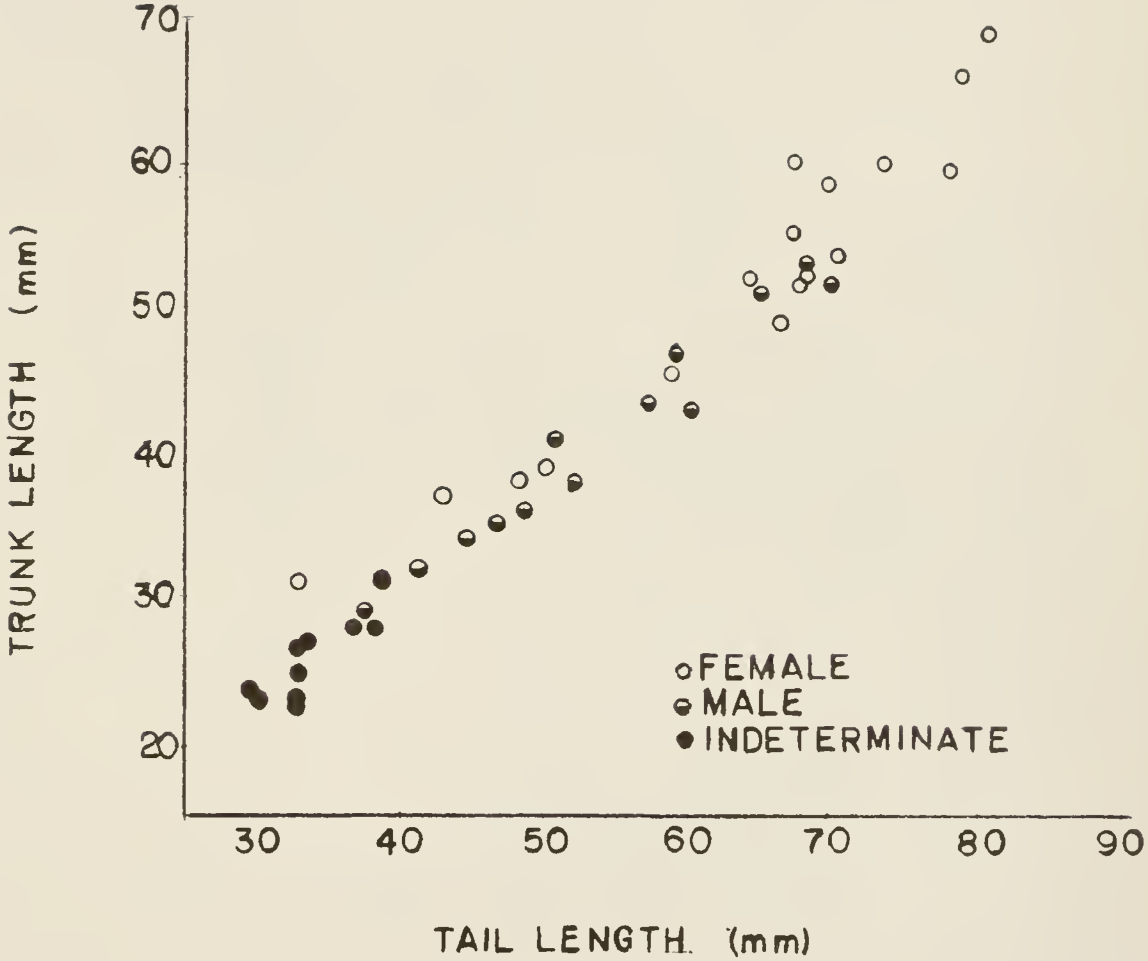
Florida Keys
n=36
Everglades Nat. Park
n=21
Gasparilla Sound
n=40
Tampa Bay
n=35
Cedar Key
n=31
Alligator Harbor
n=31
Pensacola
n=52
Santa Fe River
n=24
1.10
1.15
1.20
1.25
1.30
1.35
1.40
1.45
1.50
1.55
TAIL LENGTH/ TRUNK LENGTH RATIO

Gasparilla Sound population in Figure 11. Again, allometric growth is not indicated.

These results indicate that morphological variation is limited in the Florida populations of *S. scovelli*. Generally, variable characters tend to express a north-south clinal pattern, but the pattern is never conclusive. *S. scovelli* usually breeds throughout the year in Florida, which tends to obscure any effects of temperature on morphogenetic processes. Effects of salinity are even less clear. The two freshwater populations often occupy distant positions on the range of variation for various morphological characters. The freshwater population in the Santa Fe River is the most distinct. The results of Joseph (1957) were similar for this population. This Santa Fe River population probably has little or no gene interchange with saltwater populations in the Gulf of Mexico. This may not be true of the freshwater population in the upper St. Johns River. The population in Lake George generally varies only slightly from coastal populations.

Figure 11. Trunk length plotted against tail length in *Syngnathus scovelli* from Gasparilla Sound, Florida.


TRUNK LENGTH (mm)
70
60
50
40
30
20
TAIL LENGTH (mm)
30
40
50
60
70
80
90
○ FEMALE
◒ MALE
● INDETERMINATE

SEASONAL ABUNDANCE

Only two species, S. scovelli and S. floridae, were recorded in the Cedar Key area in every month of the study. S. louisianae and M. crinigerus were taken monthly from June, 1969, to November, 1969; and additional specimens of M. crinigerus were collected in November, 1968. These patterns of seasonal abundance generally correspond with results of earlier faunistic studies at Cedar Key (Reid, 1954) and Tampa Bay (Springer and Woodburn, 1960). In the latter investigation S. floridae was absent in collections made in the months of October, December, January, March, and May.

Numbers of specimens taken each month in the Cedar Key area are shown in Table 8. Data of this type are subject to numerous errors resulting from collecting techniques, although they are useful in providing a general picture of seasonal and relative abundance. S. scovelli is the most abundant pipefish in the Cedar Key area, followed by S. floridae. Previous studies have shown this species to be the most numerous pipefish on the west coast of Florida (Reid, 1954; Springer and Woodburn, 1960) and on the Texas Gulf coast (Gunter, 1945), but Joseph and Yerger (1956) reported S. louisianae as the most abundant syngnathid at Alligator Harbor in the northern Gulf of Mexico. S. louisianae is relatively rare at other localities. Only 18 specimens were taken in regular collections during this study. M. crinigerus is also seldom encountered in most areas. Twenty-seven

Table 8. Total Numbers and Average Numbers of Specimens per Collection Taken Each Month in the Cedar Key, Florida, Area. Average Numbers per Collection Given in Parentheses.

Month	No. Colls.	*S. scovelli*	*S. floridae*	*S. louisianae*	*M. crinigerus*
September, 1968	7	106(15.1)	96(13.7)	1(0.1)	0
October, 1968	0	--	--	--	--
November, 1968	6	106(17.7)	44(7.3)	0	8(1.3)
December, 1968	5	15(3.0)	2(0.4)	0	0
January, 1969	8	15(1.9)	6(0.8)	0	0
February, 1969	7	13(1.9)	4(0.6)	0	0
March, 1969	6	11(1.8)	12(2.0)	0	0
April, 1969	14	90(6.4)	80(5.7)	0	0
May, 1969	16	76(4.8)	100(6.3)	0	0
June, 1969	10	246(24.6)	207(20.7)	2(0.2)	1(0.1)
July, 1969	10	659(65.9)	126(12.6)	1(0.1)	2(0.2)
August, 1969	10	560(56.0)	368(36.8)	8(0.8)	3(0.3)

Table 8. Continued

Month	No. Colls.	*S. scovelli*	*S. floridae*	*S. louisianae*	*M. crinigerus*
September, 1969	10	283(28.3)	232(23.2)	1(0.1)	7(0.7)
October, 1969	10	206(20.6)	213(21.3)	1(0.1)	2(0.2)
November, 1969	10	180(18.0)	163(16.3)	3(0.3)	4(0.4)
December, 1969	5	35(7.0)	16(3.2)	1(0.2)	0
Totals	134	2601(19.4)	1669(12.5)	18(0.1)	27(0.2)

individuals of this species were taken in this study.

Peak abundance of *S. scovelli* and *S. floridae* in the Cedar Key area occurs in late summer (Table 8). Their numbers begin declining in fall, and they become scarce during the winter months when the shallow flats become nearly devoid of vegetation. Spring shows a proliferation of young pipefishes on the flats, and their numbers steadily increase to the late-summer peak. These results indicate that *S. louisianae* and *M. crinigerus* are present on the shallow flats during summer and fall, but apparently they are never abundant in the area.

ENVIRONMENTAL FACTORS

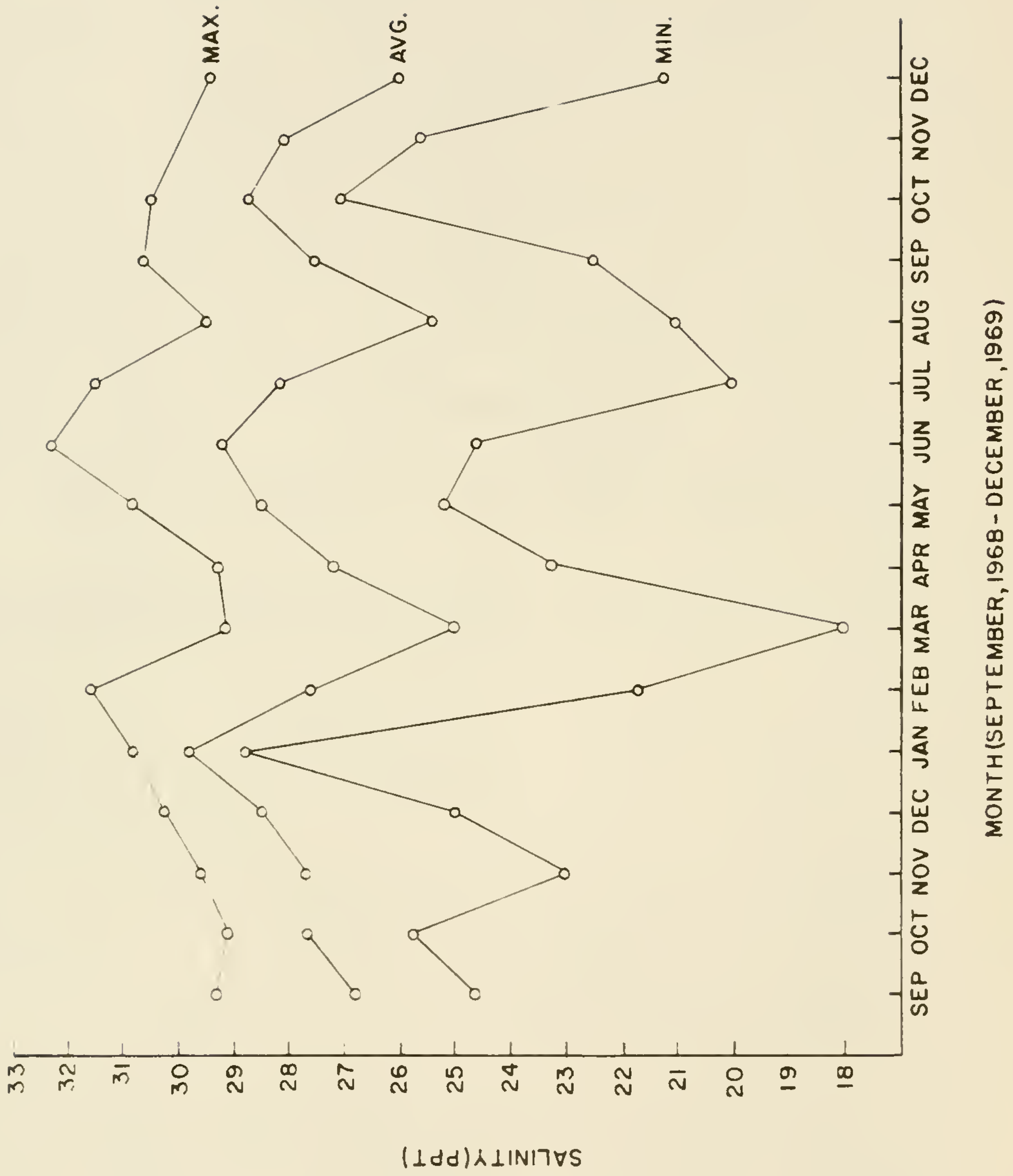
Salinity

Minimum, maximum, and average monthly salinities at Cedar Key for the period of September, 1968, to December, 1969, are shown in Figure 12. These values were obtained from records of the Coast and Geodetic Survey and are based on an average of 19 observations per month at the Cedar Key Tide Station. Average monthly salinity varied from 25.0 to 29.8 ppt during this time. Minimum and maximum salinities were 18.0 ppt and 32.4 ppt, respectively. Salinities at collecting stations fell within this range except for a value of 32.8 ppt recorded in September, 1969.

Minimum salinities occurred during early spring and late summer, and maximum values occurred during winter and early summer. These results generally resemble the yearly pattern of salinity described by Reid (1954) for the Cedar Key area. Salinity at Cedar Key tends to vary as a result of fluctuations in the discharge of fresh water from the nearby Suwannee and Waccasassa rivers. These are sizable streams; thus the amount of rainfall in their respective basins influences salinity in this area.

S. scovelli is a euryhaline species (Gunter, 1942) and has been taken in waters ranging from fresh to hypersaline. Simmons (1957)

Figure 12. Monthly salinities at the Cedar Key, Florida, Tide Station for the period of September, 1968, to December, 1969.


MAX.
AVG.
MIN.
SALINITY(PPT)
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
18
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH(SEPTEMBER,1968-DECEMBER,1969)

recorded this species in salinities up to 45.0 ppt in the Laguna Madre of Texas, and Hoese (1960) found them in salinities up to 45.4 ppt in Mesquite Bay on the Texas coast. Reid (1954) collected *S. scovelli* in salinities ranging from 19.9 to 30.0 ppt at Cedar Key. Freshwater populations in the Santa Fe and St. Johns rivers, Florida, and Lake St. John, Louisiana, have previously been described.

The St. Johns River in Florida forms an extensive area of oligohaline water (100-1,000 ppm Cl), with chlorinity values as high as 900 ppm (Odum, 1953). The inland distributions of many marine fishes and Blue crabs, *Callinectes sapidus*, suggest that sodium chloride in the oligohaline concentration range is important to the survival of marine organisms invading freshwater in Florida (Odum, 1953). This fails to explain the presence of freshwater populations of *S. scovelli* in the Santa Fe River and Lake St. John. Chlorinity in the Suwannee-Santa Fe System is generally 8 ppm or less (Odum, 1953). The concentration of calcium is a factor that might be involved. Studies by Breder (1933) indicate that calcium provides protection to marine teleosts from the detrimental effects of the lower tonicity of fresh water. The mechanism of osmotic regulation in this species is unknown and is an area worthy of investigation. *S. scovelli* presumably has an aglomerular kidney, as do other syngnathids.

S. floridae, *S. louisianae*, and *M. crinigerus* apparently exhibit less tolerance for variations in salinity. Reid (1954) collected *S. floridae* at Cedar Key in salinities ranging from 17.5 to 30.0 ppt, and Springer and Woodburn recorded a range of 25.5 to 35.0 ppt for this species at Tampa Bay. The lowest published value for *S. floridae*, 12.3

ppt, was obtained in Aransas Bay, Texas (Gunter, 1945).

Salinity records are less numerous for _S. louisianae_ and _M. crinigerus_. In this study _S. louisianae_ was taken in salinities ranging from 24.2 ppt (August, 1969) to 31.4 ppt (July, 1969). _M. crinigerus_ occurred in salinities ranging from 24.2 ppt (August, 1969) to 30.8 ppt (June, 1969). Reid (1954) recorded a range of 18.3 to 33.8 ppt for _S. louisianae_ at Cedar Key, and Springer and Woodburn (1960) collected this species in salinities ranging from 21.0 to 35.0 ppt in Tampa Bay. The maximum published value for _S. louisianae_, 45.5 ppt, was recorded in the Laguna Madre of Texas (Simmons, 1957). In Florida's St. Johns River, _S. louisianae_ has been taken in completely fresh water (Tagatz, 1968). Springer and Woodburn (1960) recorded a range of 23.6 to 30.8 ppt for _M. crinigerus_ at Tampa Bay, and Kilby (1955) reported a single value of 31.1 ppt for this species at Cedar Key.

Temperature

At Cedar Key the areas inhabited by pipefishes are subject to wide fluctuations in temperature. Minimum, maximum, and average monthly water and air temperatures for the period of September, 1968, to December, 1969, are shown in Figures 13 and 14, respectively. These were also taken from records of the Coast and Geodetic Survey and were recorded concurrently with salinity data. Minimum water temperature recorded during this time was 7.8°C; maximum was 33.0°C. Average temperature varied from 12.7°C in December, 1968, to 30.2°C in

Figure 13. Monthly water temperatures at the Cedar Key, Florida, Tide Station for the period of September, 1968, to December, 1969.

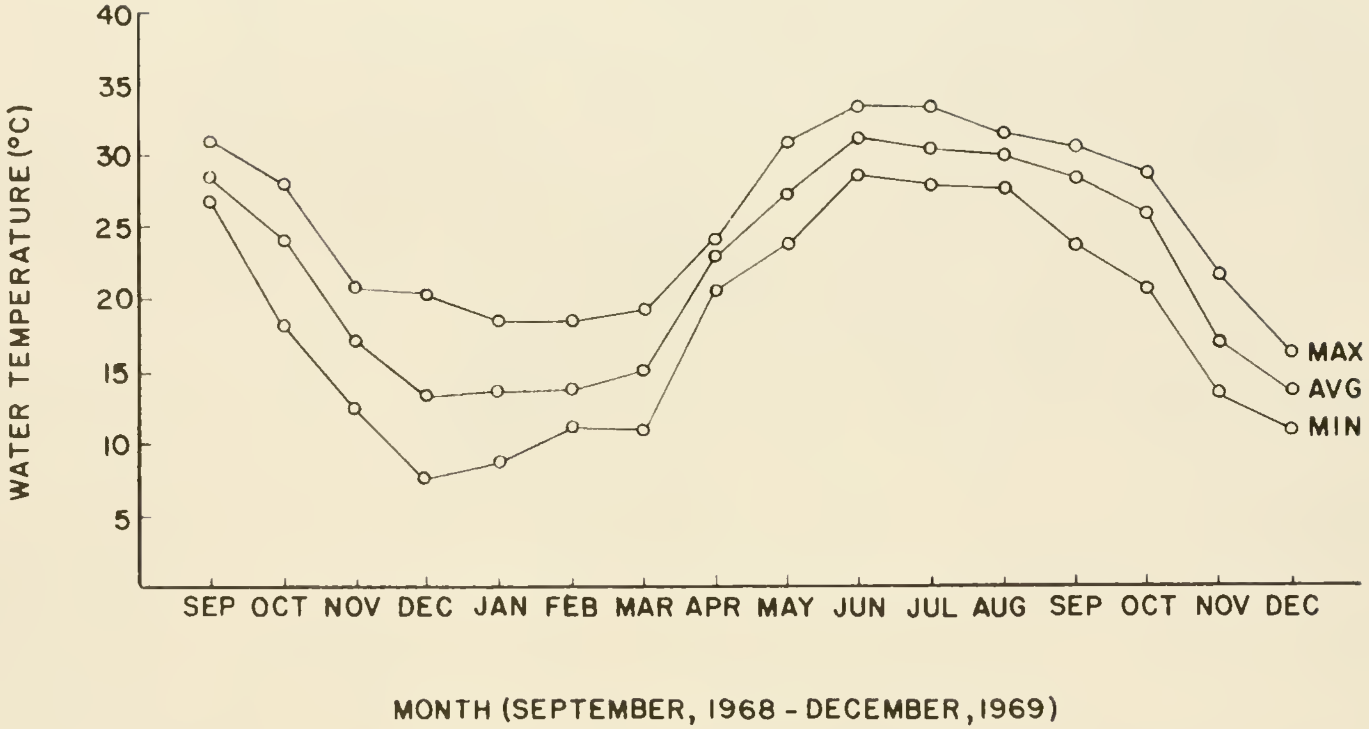
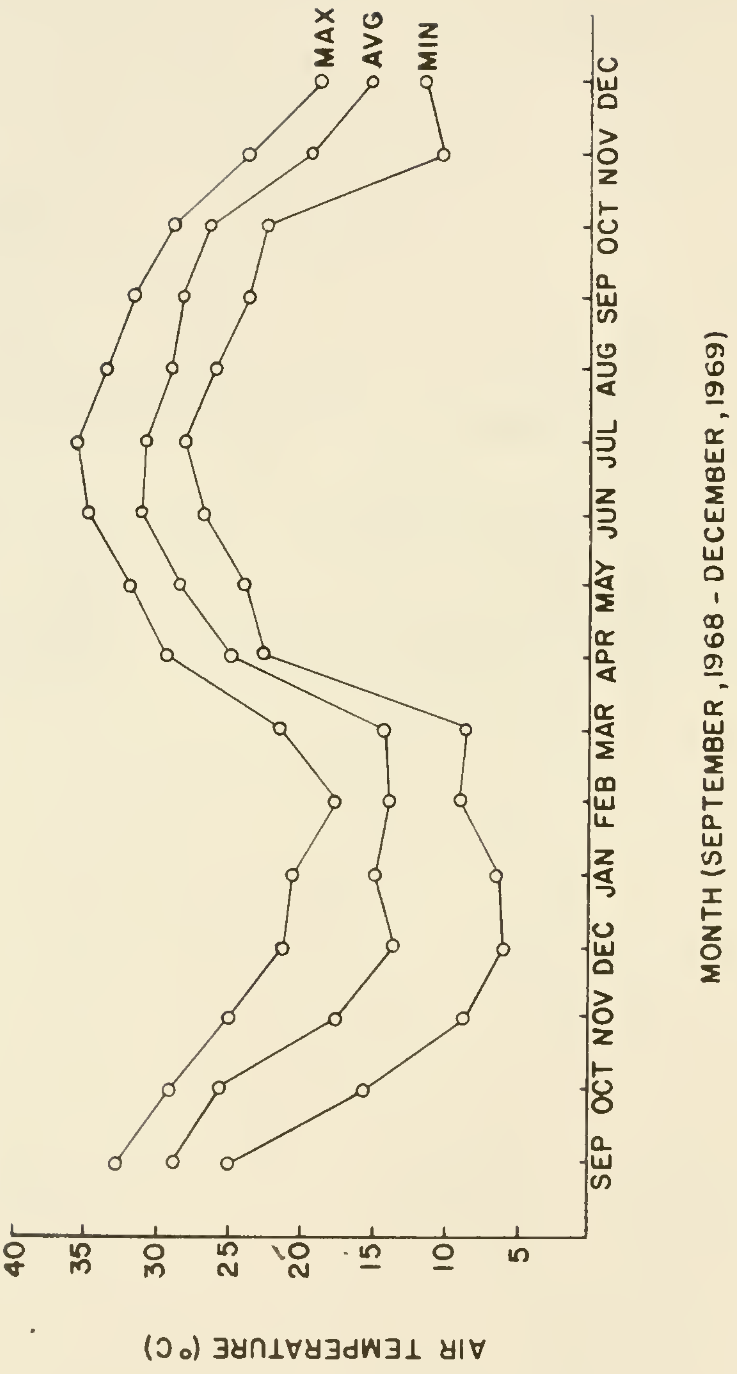

WATER TEMPERATURE (°C)
40
35
30
25
20
15
10
5
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MAX
AVG
MIN
MONTH (SEPTEMBER, 1968 - DECEMBER, 1969)

Figure 14. Monthly air temperatures at the Cedar Key, Florida, Tide Station for the period of September, 1968, to December, 1969.


AIR TEMPERATURE (°C)
40
35
30
25
20
15
10
5
SEP OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTH (SEPTEMBER, 1968 - DECEMBER, 1969)
MAX
AVG
MIN

July, 1969. Generally, water temperature paralleled air temperature. Air temperature, however, tended to fluctuate much more rapidly, and the range between yearly extremes was greater. Air temperature during this period ranged from a low of 6.2° C in December, 1968, to a maximum of 35.8° C in July, 1969. Average air temperature ranged from 13.4° to 28.2° C.

The range of water temperatures obtained in this study was slightly greater than the values reported for *S. scovelli* and *S. floridae* at Cedar Key by Reid (1954). He recorded a range of 12.2° to 28.9° C for *S. scovelli* and 10.0° to 30.6° C for *S. floridae*. Some members of these two species are always present in the Cedar Key area; hence they must endure whatever temperatures occur during the year. The decrease in abundance of these fishes in winter months may result from a dispersal into deeper waters offshore in search of more equitable temperatures. The minimum published temperature recorded for *S. scovelli* is 10.0° C at Tampa Bay (Springer and Woodburn, 1960), and the maximum is 33.8° C in the St. Johns River (Tagatz, 1968). Minimum and maximum values for *S. floridae* are 10.0° C at Cedar Key (Reid, 1954) and 32.5° C at Tampa Bay (Springer and Woodburn, 1960).

S. louisianae was collected at Cedar Key in temperatures ranging from 15.0° C (December, 1969) to 32.0° C (June, 1969). *M. crinigerus* occurred in temperatures ranging from 17.0° C (November, 1969) to 31.0° C (July, 1969). Minimum and maximum published values for *S. louisianae* are 10.0° C at Cedar Key (Reid, 1954) and 33.8° C in the St. Johns River (Tagatz, 1968). Published temperatures for *M. crinigerus* range from a low of 7.0° recorded in Tampa Bay (Springer and Woodburn, 1960) to a high of 25.0°C at Cedar Key (Kilby, 1955).

The northern Gulf coast is transitional between subtropical and temperate. Seasonal variation in temperature is fairly sizable but not extreme. All four species of pipefishes studied range into areas with a tropical climate; but only *S. floridae* and *S. louisianae*, both of which are found in Virginia waters, extend any distance into the temperate zone. *S. scovelli* and *M. crinigerus* reach their northernmost limits in the northern Gulf of Mexico. A number of ecological and evolutionary factors can influence the geographical distribution of a species; however, the ranges of *S. scovelli* and *M. crinigerus* suggest that they are less tolerant of low temperatures than *S. floridae* and *S. louisianae*.

The Gulf of Mexico is occasionally subjected to cold polar fronts pushing southward. Because of the physiography of the inshore Gulf waters, massive mortalities of marine life frequently result from these northers (Gunter, 1952). The extent of these mortalities depends upon the drop in temperature, minimum temperature attained, direction and velocity of wind, and stage and range of tides (Storey, 1937). Heavy fish kills resulting from these polar fronts have occurred on the southern Texas coast in the Aransas Bay area (Gunter, 1941; Gunter and Hildebrand, 1951) and along the southwestern Florida coast at Sanibel Island (Storey and Gudger, 1936; Storey, 1937) and Key West (Finch, 1917; Miller, 1940; Galloway, 1941). Pipefishes have been included in documented lists of fishes killed on the Texas coast, but sea horses are the only members of the family Syngnathidae listed as killed by cold in Florida. Since these lists have been rather general and limited in nature, the absence of pipefishes in them is probably a result of the brevity of work on this subject.

Depth

Generally, the pipefishes under investigation are considered to be limited to shallow inshore waters. These fishes are most often associated with underwater vegetation which is usually limited to depths of twelve to fifteen feet in the northern Gulf of Mexico, depending upon water clarity. Most of the specimens collected in this study were caught in water ranging from three to eight feet in depth. *S. scovelli* and *S. floridae* occurred regularly on both shallow and deep flats. In general, *S. scovelli* seemed to be a little more common on the shallow flats, whereas *S. floridae* was taken slightly more often on deep flats.

The occasional collections made at the deep-water Station 6 produced few pipefishes. Even though this station was sampled during all seasons, only 11 specimens of *S. scovelli* and five of *S. floridae* were collected there. Collections at this station yielded no specimens of *S. louisianae* or *M. crinigerus*. Exploratory collections were made periodically in the deeper channels, but these also rarely produced pipefishes. In collections of this type there is always the possibility of taking fish at the shallow edges of these channels since they are meandering and irregular in width.

Of the four species in this study, *S. louisianae* apparently is found at the greatest depth, even though none was taken in deep-water collections at Cedar Key. Hildebrand (1954), in a study of the fauna of the Brown shrimp grounds in the western Gulf of Mexico, reported the collection of two specimens of S. louisianae in 6.5 fathoms on the edge of Sabine Banks, eight specimens in 12 to 18 fathoms off Padre Island, and a single specimen in 17 fathoms off Obregon. In a later study Hildebrand (1955) reported a gravid male, 305 mm in length, taken in eight fathoms in the Gulf of Campeche. The deepest record encountered in this investigation was a single specimen taken in 20 fathoms of water at Silver Bay Station 3620, Latitude 34°40' N, Longitude 75°57' W. This specimen is in the uncataloged fish collection at the Tropical Atlantic Biological Laboratory.

Tidal and Wave Action

Pipefishes, being inhabitants of shallow inshore areas, are more subject to the effects of tides and waves than species found in deeper waters. In the Cedar Key area the flats are exposed to fairly strong tidal and wave movements. Tidal amplitude in this area is not large, but many flats are so shallow they are partially exposed during extremely low tides. This is more common during winter months but can occur at any time of the year. During some of these periods of low water the less mobile small fishes, including pipefishes, are concentrated in shallow pools formed on the uneven surfaces of the shallow flats. These flats may be out of the water an hour or more, and during this time a variety of wading birds feed over these areas. It seems likely that pipefishes would be susceptible to predation by these birds.

Wind is an important factor influencing both tidal and wave action in this area (Reid, 1954). Strong winds blowing from offshore for a period of several days can keep the inshore area in an almost constant state of high tide. Conversely, winds from over the mainland can keep the water at low tide level. In this shallow area sizable waves buffet the flats during periods of strong wind. This wave action, combined with tidal currents, results in a thorough mixing of the waters in the area. Thus thermal or salinity stratification has little chance to develop in this environment.

Associated Fish Species

The inshore flats inhabited by pipefishes serve as important nursery and feeding grounds for a variety of fishes, and these areas literally teem with larval and juvenile fishes during the summer and early fall. Some fishes commonly found with pipefishes at Cedar Key are Spotted sea trout, *Cynoscion nebulosus*, Pigfish, *Orthopristes chrysoptera*, Pinfish, *Lagodon rhomboides*, Silver perch, *Bairdiella chrysura*, Silver jenny, *Eucinostomus gula*, Striped burrfish, *Chilomycterus schoepfi*, and Florida blenny, *Chasmodes saburrae*. The Cedar Key area has a rich assemblage of fishes, and many of these are present on the flats at one time or another. Reid (1954) included 122 species in his comprehensive study of the fishes of this region.

Since then additional species have been added to the list by Caldwell (1954, 1955, 1957) and Berry (1957, 1958).

Little information is available concerning fish predators of pipefishes. The dense grass beds where they are usually found are feeding grounds for many fishes, such as the Spotted sea trout; and pipefishes probably play some role in the diet of these predators. Darnell (1958) reported the presence of *Syngnathus* sp. in the stomach contents of Blue catfish, *Ictalurus furcatus*, Atlantic croaker, *Micropogon undulatus*, and Red drum, *Scianops ocellata* from Lake Ponchartrain, Louisiana. These food items were not identified to the species level, but it seems likely any of these pipefishes would be taken by piscivorous predators if available.

REPRODUCTION

The external brood pouch of males and distended trunk region of females make the determination of sex relatively simple for sexually mature pipefishes. All individuals collected in this investigation were examined with respect to sex. Males with fully developed pouches were considered to be sexually mature, whereas individuals with pouches in the process of forming were considered to be immature. Sexually mature females were identified by the distended trunk region and the presence of ripe ova in ovaries as revealed by dissection of the body cavity. Smaller specimens lacking these sexual characteristics were considered sex-indeterminate. Specimens from other Florida localities were examined in order to make comparisons with Cedar Key data.

Sexual Maturity

The obvious sexual characteristics exhibited by pipefishes facilitate an investigation of the size at which sexual maturity is attained, although there is only a limited amount of published information available on this subject. Immature males with partially formed pouches provide data on the development of the brood pouch and the size at which this process occurs. In the pipefishes considered here, evidence of the brood pouch first appears as a pair of fleshy ridges radiating posteriorly from the vent. As development occurs these fleshy ridges fold inward and grow medially until they meet, completing the enclosed pouch. This development proceeds from anterior to posterior; thus, the posterior portion of the pouch is the last to become completely enclosed by the fleshy folds. S. scovelli, S. floridae, and S. louisianae belong to the inverted-brood-pouch-closure group of Herald (1959), in which the two folds extend downward about halfway into the center of the pouch. M. crinigerus is a member of the everted-brood-pouch-closure group (Herald, 1959), in which the underlapping edge of the folds is turned back upon itself. The brood pouch is open between the folds along its complete length in all four species.

Sexually mature males of S. scovelli collected at Cedar Key ranged from 64.0 to 128.5 mm in length. Immature males in which external development of the brood pouch was discernible ranged from 68.0 to 100.0 mm in length. Individuals at the lower end of this range usually had a brood pouch in the initial stages of development, whereas larger specimens usually exhibited a nearly completed pouch. These data demonstrate that size at which sexual maturity is attained by males varies considerably in this species. Mean monthly standard lengths of sexually mature males were less than 100.0 mm for six of the 15 months during which collections were made. The range of monthly means was 88.3 to 107.1 mm.

Generally, females of S. scovelli become sexually mature at a larger size than males. Some 218 sexually mature females with ripe ova collected at Cedar Key during the period of September, 1968, to August, 1969, were dissected. These ranged in length from 90.5 to

135.0 mm. Many other females in the 90 to 100 mm range had tiny ova in the process of developing. No ovarian development was evident in females less than 80 mm in length.

Male specimens of S. scovelli from Everglades National Park in extreme southern Florida and from Lake George yielded results similar to those obtained at Cedar Key. Of 26 males from Everglades National Park, all except one were sexually mature. These ranged from 60.0 to 112.0 mm in length, whereas the immature male measured 68.0 mm. All except 15 of 108 males from Lake George were sexually mature. The 15 immature males measured from 63.5 to 104.0 mm, and the 93 mature males ranged from 72.0 to 109.0 mm in length. These size ranges obviously coincide with those obtained at Cedar Key, with the exception of the larger males in Cedar Key collections. McLane (1955) noted that males from the St. Johns River did not attain as large a size as those from Cedar Key, but results obtained in this study suggest little if any difference in the size at which sexual maturity is attained at different geographical locations.

The smallest size at which evidence of a brood pouch is discernible in S. scovelli seems to be 60 mm over most of Florida. Most males have achieved sexual maturity by the time they reach the 90-100 mm size range. Springer and Woodburn (1960) collected males with brood pouches as small as 60 mm at Tampa Bay, but it is likely that the smaller specimens did not have a completely formed brood pouch.

Sexually mature males of S. floridae taken in the vicinity of Cedar Key ranged from 102.0 to 199.0 mm in length. The smallest individual with a brood pouch in the process of development was 105.0

mm long, and the largest measured 167.0 mm. Reid (1954) collected pregnant males of *S. floridae* ranging from 116.0 to 176.0 mm at Cedar Key. The smallest male of this species with an external pouch taken at Tampa Bay by Springer and Woodburn (1960) measured 116.2 mm in length.

Most of the males of *S. floridae* examined from other Florida locations were large specimens; consequently, these provided little information on size at which sexual maturity is reached in this species. All 22 males examined from the Florida Keys and Everglades National Park were sexually mature and ranged from 134.0 to 240.5 mm in length. Five of 35 males from Alligator Harbor exhibited brood pouches in various stages of development. These specimens ranged from 139.0 to 161.5 mm in length. The 30 mature males measured from 131.0 to 177.0 mm in length.

Sexual maturity is reached over a wide size range in males of *S. floridae* also. Nevertheless, because of the larger size of this species, brood pouch development occurs at a greater length than in *S. scovelli*. Mean monthly lengths of sexually mature males varied from 121.5 to 172.3 mm during the 13 months in which specimens of *S. floridae* were collected at Cedar Key. This value exceeded 150 mm for six of those months, indicating that most males have become sexually mature by the time they reach the 140-150 mm size range.

Some 132 sexually mature females of *S. floridae* with large ova collected between September, 1968, and August, 1969, were dissected. The smallest female with ripe ova measured 121.5 mm, and the largest measured 201.0 mm. Females carrying tiny ova in the process of developing were common in the 120 to 140 mm size range, although many specimens of less than 140 mm in length showed little or no ovarian development. These data indicate that most females of *S. floridae* in the Cedar Key area greater than 140 mm in length are sexually mature.

The size at which sexual maturity is attained in *S. louisianae* and *M. crinigerus* is more difficult to ascertain because of the relative paucity of these species in collections. *S. louisianae* is the largest species studied, and *M. crinigerus* is the smallest. Accordingly, the size at which these species become sexually mature should reflect their relative sizes.

No sexually mature males or females of *S. louisianae* were included in the 18 specimens collected in the vicinity of Cedar Key. Reid (1954) obtained identical results in his study at Cedar Key. Springer and Woodburn (1960) collected 58 specimens of *S. louisianae* at Tampa Bay; but only one of those, a non-pregnant male measuring 116.2 mm in length, exhibited any external development of a brood pouch. Joseph and Yerger (1956) stated that larger males at Alligator Harbor contained eggs. But only a general size range of 125 to 185 mm for all specimens was given, which seems low for *S. louisianae*. This species probably spawns in deeper water offshore, making the capture of breeding individuals unlikely in studies of this type.

Ten males and seven ripe females of *S. louisianae* from other Florida localities were examined. Two of the males exhibited brood pouches in the early stages of development, and the other eight were sexually mature. The two immature males measured 182.0 and 252.0 mm in length, whereas mature males ranged from 203.0 to 294.5 mm in length. The smallest of these mature males had been collected at Merritt Island and the largest at Everglades National Park. The two smallest females with ova, 130.5 and 155.0 mm in length, had been collected from the lower St. Johns River near Jacksonville. The other five ripe females, representing scattered Florida localities, ranged from 221.5 to 281.5 mm in length.

Only two males of _M_. _crinigerus_, both sexually mature, occurred in regular collections made at Cedar Key. One male, 81.0 mm in length, carried no eggs; and the other, 80.0 mm in length, carried 23 eggs in its brood pouch. Powell and Strawn (1963) collected several males in their study of _M_. _crinigerus_ at Cedar Key and Tampa Bay, but none of these was less than 60 mm long.

Five males of _M_. _crinigerus_, collected at Cedar Key by G. K. Reid, measured from 62.0 to 73.0 mm in length. One of these, 68.5 mm long, had a brood pouch in an early stage of development. Thirteen other males from the Florida Keys, all with completely developed brood pouches, ranged from 60.0 to 76.5 mm in length.

Two females of _M_. _crinigerus_ with large ova were collected at Cedar Key. These ripe females measured 64.0 and 76.0 mm in length. Other females, ranging from 51.5 to 77.5 mm in length, contained tiny developing ova. Six females with well developed eggs examined from other Florida locations ranged from 60.5 to 79.5 mm in length.

Seasonality of Reproduction

Several factors must be considered in order to determine seasonal reproductive cycles in fishes. These include the presence or absence of sexually mature individuals in the population, the proportion of these adults in breeding condition, and the extent of gonadal development. Taken together these should provide some indication of the relative degree of reproductive activity in different periods of the year.

Inasmuch as pipefishes produce only limited numbers of eggs, it is relatively easy to count the number of eggs or embryos carried in the brood pouches of males during different seasons. The size of adults varies considerably during the year, and thus these values might reflect seasonal differences in size of males rather than actual changes in reproductive activity. Gonosomatic ratio, the ratio of gonad weight to body weight, is frequently used to illustrate seasonal change in reproductivity. In this study the number of embryos per centimeter of standard length carried by males of _S_. _scovelli_ and _S_. _floridae_ was used instead since brood counts were made for a number of males of these species collected in each month. This should provide essentially the same information as gonosomatic ratio.

Previous workers have indicated that _S_. _scovelli_ breeds continually in many areas. Reid (1954) collected gravid males and females during every month of the year at Cedar Key, with no indication of a seasonal decrease in reproductive activity of this species during winter months. Other studies in the St. Johns River (McLane, 1955) and Santa Fe River (Hellier, 1967) have produced similar results. In contrast, studies in other areas suggest the possibility of distinct breeding seasons for S. scovelli. Whatley (1969) collected pregnant males in Lake St. John, Louisiana, from March through October. No males were encountered from November through February, but the absence of pregnant males in collections does not necessarily preclude spawning during this time. Gunter (1945) collected males carrying embryos in June, August, October, and November on the Texas coast, suggesting that spawning occurs in summer and fall in this part of the range of S. scovelli.

At Cedar Key sexually mature males and females of S. scovelli in breeding condition occurred in regular collections during every month, but only limited numbers were taken from December, 1968, through March, 1969. These months represent a general period of decreased abundance of all pipefishes in the Cedar Key area (Table 8). This presence of pregnant males and females with large ripe ova during all months demonstrate that this species breeds year round in this region. The number of sexually mature males of S. scovelli collected each month at Cedar Key, the percentage of these carrying embryos, the mean number of embryos carried by these males, and the mean number of embryos per centimeter of standard length are given in Table 9. The percentage of mature males with incubating embryos varied from 50% in December, 1968, to 100% in September, 1968, and March and October, 1969. This percentage exceeded 90% in September, 1968, and in all months from March to October in 1969 except June and July, indicating high levels of reproduction in spring and early fall with slight decreases in early summer and late fall and winter.

Table 9. Numbers of Non-pregnant and Pregnant Males, Mean Numbers of Embryos Carried by Pregnant Males, and Mean Numbers of Embryos per Centimeter of Standard Length in *Syngnathus scovelli* from the Cedar Key, Florida, Area.

Month	No. Sexually Mature	Number Pregnant	Percentage Pregnant	Number Counted	Mean No. Eggs	Mean No. Eggs/Cm
September, 1968	26	26	100.0	25	36.2	3.7
November, 1968	27	23	85.2	19	55.4	5.4
December, 1968	4	3	75.0	3	37.0	3.5
January, 1969	5	4	80.0	3	15.0	1.6
February, 1969	2	1	50.0	1	24.0	2.5
March, 1969	2	2	100.0	2	54.0	6.1
April, 1969	34	32	94.1	26	53.5	5.3
May, 1969	31	28	90.3	26	101.0	9.3
June, 1969	55	48	87.3	44	77.4	7.4
July, 1969	136	107	78.7	39	46.5	4.9
August, 1969	190	177	93.2	44	39.9	4.2
September, 1969	139	137	98.6	35	46.2	4.7
October, 1969	96	96	100.0	34	62.4	5.9
November, 1969	45	38	84.4	34	52.8	5.0
December, 1969	15	13	87.0	12	41.3	4.0
Totals	807	735	91.1	347	55.6	5.4

Monthly mean numbers of embryos per centimeter in _S. scovelli_ ranged from a low of 1.6 in January, 1969, to a high of 9.3 in May, 1969 (Table 9). Largest values occurred during the period of April through June, corresponding with an increase in percentage of males carrying embryos and suggesting that reproductive activity reaches a peak in spring.

Sexually mature males of _S. floridae_ were taken in regular collections during all months except December, 1968, through February, 1969 (Table 10). Ripe females with large eggs were encountered during every month except January, 1969. The percentage of males with embryos was considerably lower than in _S. scovelli_ for almost every month. This figure ranged from a low of 28.6% in November, 1968, when only seven males were taken, to a high of 95.8% in May, 1969. These results indicate a high level of reproduction from April through October. Peak values occurred in the months of May, August, September, and October. Reproductive activity during winter months is apparently at a low level at Cedar Key, as indicated by the absence of pregnant males and the relative scarcity of this species in the area. Nevertheless, the paucity of breeding males in this particular study does not necessarily rule out spawning during this season.

Reid (1954) collected males of _S. floridae_ with young in the brood pouch at Cedar Key during every month except December. Greatest abundance of gravid males occurred from July through October, whereas fewer pregnant males were present from November through January. Springer and Woodburn (1960) encountered pregnant males at Tampa Bay from April through November, with the majority occurring during August

Table 10. Numbers of Non-pregnant and Pregnant Males, Mean Numbers of Embryos Carried by Pregnant Males, and Mean Numbers of Embryos per Centimeter of Standard Length in *Syngnathus floridae* from the Cedar Key, Florida, Area.

Month	No. Sexually Mature	Number Pregnant	Percentage Pregnant	Number Counted	Mean No. Eggs	Mean No. Eggs/Cm
September, 1968	25	23	92.0	18	287.2	18.8
November, 1968	7	2	28.6	1	240.0	14.5
December, 1968	0	--	--	--	--	--
January, 1969	0	--	--	--	--	--
February, 1969	0	--	--	--	--	--
March, 1969	2	1	50.0	1	312.0	25.4
April, 1969	26	17	65.4	15	270.1	20.1
May, 1969	24	23	95.8	23	438.5	29.8
June, 1969	27	13	48.1	12	259.2	18.6
July, 1969	25	19	76.0	19	352.9	23.1
August, 1969	71	62	87.3	44	380.0	23.5
September, 1969	31	30	96.8	26	342.9	21.8
October, 1969	18	15	83.3	13	402.9	25.0
November, 1969	8	4	50.0	4	585.5	33.6
December, 1969	2	1	50.0	1	399.0	24.2
Totals	266	210	78.9	177	357.6	23.1

and September.

Although *S. floridae* is a much larger species than *S. scovelli*, its eggs are smaller in size, resulting in a considerably greater number of embryos carried by pregnant males (Table 10). This, of course, results in a larger number of embryos per centimeter of standard length in this species. Monthly means varied from 14.5 in November, 1968, to 33.6 in November, 1969 (Table 10). The small sample of males taken in November of both 1968 and 1969 possibly accounts for this large difference between the same month in two different years. Mean number of embryos per centimeter exceeded 20 for all months from April through October except June, coinciding with peak values for both the abundance of this species and the percentage of males incubating eggs.

The failure to obtain breeding males or females of *S. louisianae* in regular collections limited the investigation of seasonal reproductive cycles in this species. Some 200 specimens from other Florida localities were examined, but only eight of these were sexually mature males with completely developed brood pouches. Only seven were females with ripe ova. Location, date of collection, collection number, length, and number of embryos carried are given in Table 11 for the eight mature males. Seven of these individuals were gravid and had been collected in the months of January, April, August, and December. The seven females with ripe ova represented the months of April, July, August, and September.

These few data suggest that spawning in *S. louisianae* occurs through the spring, summer, fall, and possibly winter in Florida

Table 11. Number, Location, and Date of Collection, Length, and Number of Embryos for Sexually Mature Males of *Syngnathus louisianae* in Florida

Collection Number	Location of Collection	Date of Collection	Standard Length	Number of Embryos
UMML 1658	Merritt Island	18 Aug, 1956	207.0	0
UMML 1658	Merritt Island	18 Aug, 1956	203.0	746
TABL uncat.	Virginia Key	25 Jan, 1969	268.0	554
TABL uncat.	Virginia Key	11 Jan, 1969	233.0	+*
UMML 8406	Everglades Nat. Park	17 Dec, 1958	294.5	731
UMML 5011	Cape Sable	23-24 Apr, 1958	266.5	898
UMML 4750	Bonita Springs	14 Aug, 1957	211.0	605
FSU 10939	St. George Sound	28 Apr, 1960	236.0	454

* Embryos present but not counted.

waters. Gravid males representing late fall and winter months had been collected at southern Florida locations, presenting the possibility that spawning occurs over a larger part of the year in these warmer waters.

Published data for S. louisianae is as scanty as that obtained in this study. Joseph and Yerger (1956) reported that brood pouches of males collected at Alligator Harbor in September were filled with eggs. Gravid males have also been taken in the western Gulf of Mexico in July (Hildebrand, 1954) and in the Gulf of Campeche in February (Hildebrand, 1955).

Of the two sexually mature males of M. crinigerus taken at Cedar Key, the specimen collected in November, 1968, did not carry embryos. The other, taken in August, 1969, contained developing embryos in its brood pouch. The two ripe females collected at Cedar Key were taken in August and September, 1969.

Two of the four sexually mature males of M. crinigerus collected at Cedar Key by G. K. Reid were gravid, and they had been collected in the months of April and July. A ripe female included in these Cedar Key collections had been collected in July. Six of 13 males from Biscayne Bay carrying embryos had been collected in June and August, and a single pregnant male from Tampa Bay had been collected on March 30, 1949. A ripe female was also included in this Tampa Bay collection. Five other ripe females from Biscayne Bay and the Florida Keys had been collected in the months of January, March, and June.

Powell and Strawn (1963) described M. crinigerus as having the shortest breeding season of any syngnathid found on the grass flats at Cedar Key and Old Tampa Bay. Their Cedar Key collections yielded pregnant males between April 2 and September 1 and females with yolked eggs between April 2 and September 16. In Old Tampa Bay pregnant males and ripe females were taken in March. Reid (1954) collected breeding males during May, August, and September at Cedar Key. The data presented here add only January to the list of months during which breeding specimens of _M. crinigerus_ have been recorded in Florida. A female taken in Florida Bay on January 31, 1958, contained ripe eggs, but actual spawning could have been a few weeks away. Since this location is a considerable distance south of the areas studied by Powell and Strawn (1963), the breeding season might extend over a greater part of the year in this region.

Sex Ratio

Sex ratios of syngnathids are usually quite variable, and a considerable amount of this variability was illustrated by _S. scovelli_ and _S. floridae_ in this study. The small numbers of _S. louisianae_ and _M. crinigerus_ collected prevented an analysis of sex ratio in these species. Monthly ratios of sexually mature females to sexually mature males of _S. scovelli_ and _S. floridae_ collected in the Cedar Key area are given in Tables 12 and 13, respectively. These values do not represent absolute numbers of females and males in the Cedar Key population. Instead they represent the numbers of females with substantial ovarian development, as determined by microscopic examination of intact

Table 12. Sex Ratios of Sexually Mature *Syngnathus scovelli* from Cedar Key, Florida.

Month	Females	Males	Females/Males	χ^2
Sep, 1968	65	26	2.50	16.71[a]
Nov, 1968	42	27	1.56	3.26
Dec, 1968	8	4	2.00	1.33
Jan, 1969	8	5	1.60	0.69
Feb, 1969	5	2	2.50	--
Mar, 1969	8	2	4.00	3.60
Apr, 1969	48	34	1.41	2.39
May, 1969	29	31	0.94	0.07
Jun, 1969	26	55	0.47	10.38[a]
Jul, 1969	69	136	0.51	21.90[a]
Aug, 1969	193	190	1.02	0.02
Sep, 1969	100	139	0.72	6.36[b]
Oct, 1969	53	96	0.55	12.41[a]
Nov, 1969	49	45	1.09	0.17
Dec, 1969	16	15	1.07	0.03

[a] Significant at the 99% level.
[b] Significant at the 95% level.

Table 13. Sex Ratios of Sexually Mature Syngnathus floridae from Cedar Key, Florida.

Month	Females	Males	Females/Males	χ^2
Sep, 1968	55	25	2.20	11.25[a]
Nov, 1968	19	7	2.71	5.54[b]
Dec, 1968	1	0	--	--
Jan, 1969	0	0	--	--
Feb, 1969	1	0	--	--
Mar, 1969	2	2	1.00	--
Apr, 1969	31	26	1.19	0.44
May, 1969	30	24	1.25	0.67
Jun, 1969	37	27	1.37	1.56
Jul, 1969	26	25	1.04	0.02
Aug, 1969	99	71	1.39	4.61[b]
Sep, 1969	56	31	1.81	7.18[a]
Oct, 1969	53	18	2.94	17.25[a]
Nov, 1969	21	8	2.63	5.83[b]
Dec, 1969	4	2	2.00	--

[a] Significant at the 99% level.
[b] Significant at the 95% level.

ovaries, and males with completely formed brood pouches capable of receiving and incubating fertilized eggs. Chi-square (χ^2) tests were made to determine the significance of differences in abundance between the sexes. Chi-square was not calculated for any month in which the total number of adults taken was less than ten.

Variation is greatest in *S. scovelli*, but seasonal patterns are suggested for both species. In *S. scovelli* the ratio of adult females to adult males was quite different from month to month. Females slightly outnumbered males in winter and early spring when population numbers were low. From June through October in 1969, the period of peak abundance of pipefishes, the abundance of males significantly exceeded that of females in every month except August. The only month not corresponding with this pattern was September, 1968, which was the only time in the study that females significantly outnumbered males.

The smaller size at which males of *S. scovelli* attain sexual maturity contributes to their numerical superiority during summer months. Many immature females occurred in summer and early fall collections, and they commonly exceeded 100 mm in length. Throughout the study immature males of this size were rare. Later in fall, these sizable females achieved sexual maturity; and the sexes became nearly equal in abundance.

In *S. floridae* mature females outnumbered mature males in every month in which both were present in collections except March when equal numbers of each sex were encountered. This numerical superiority ranged as high as 2.94 females for every male in October, 1969. Sex ratios were lower in summer months when females were only slightly more abundant than males. The proportion of females increased in fall and winter until they were over twice as numerous as males. This difference in abundance between the sexes was statistically significant in September and November, 1968, and from August to November, 1969. This pattern of seasonal variation generally resembled that in S. scovelli, although it was not as erratic.

Previous investigations have demonstrated variability in sex ratio in syngnathids similar to that in this study. Females, however, are usually reported to outnumber males in most populations. Females of S. scovelli have been reported as more abundant than males in most months at Lake Pontchartrain, Louisiana, and Cedar Key (Joseph, 1957) and at Tampa Bay (Springer and Woodburn, 1960). Strawn (1958) found that males of H. zosterae were about equal to females in number during winter months at Cedar Key, but in summer females greatly outnumbered males. Similar results were obtained for M. crinigerus at Cedar Key and Old Tampa Bay by Powell and Strawn (1963). Sex ratios in this species varied with season; but in general, females were more numerous than males.

The greater abundance of sexually mature males of S. scovelli recorded in this study contrasts somewhat with results of these previous studies. A possible explanation for this difference lies in the criteria used in determining monthly sex ratios. Springer and Woodburn (1960) considered all specimens longer than 60 mm without a brood pouch to be females. Criteria used by other workers were not clarified but could have been similar. Since the results of the present study demonstrate that males develop a brood pouch over a wide range of sizes, this approach can provide erroneous ratios based on larger numbers of females than actually exist in the population. The criteria used in this study were adopted in hopes of avoiding this type of error. Other possible explanations for these different results lie in the selectivity of collecting gear for sex and in differential dispersal of the sexes in the Cedar Key area. However, the seasonal variation obtained demonstrates the effectiveness of collecting gear in taking both sexes, making the former unlikely; and the latter would be difficult to detect. Collections were made regularly at scattered stations representing somewhat different habitats in an attempt to limit any effects of differential dispersal. Herald (1941) employed the same criteria used here in a study of the Western American pipefish, *Syngnathus californiensis*, and found that males outnumbered females by ratios of 1.3 to 1.8 in all but a single population in which the sexes were equal in number.

Contents of Brood Pouches

Fertilized eggs in the brood pouches of male pipefishes are arranged in rows lying both side-by-side and on top of one another. These rows usually extend the full length of the pouch. In *S. scovelli* eggs are normally aligned in two or four rows, but as many as eight rows may be present if eggs are numerous. The usual number of rows in *S. floridae* is four to eight, although some individuals with large numbers of eggs have as many as sixteen rows. The few pregnant males of *S. louisianae* encountered in this study exhibited eight to twelve rows of eggs. Males of *M. crinigerus* usually incubate a small number of eggs; and these lie in two rows, one on each side of the brood pouch. If eggs are numerous, they may be arranged in three or four rows.

Brood counts were made for 346 pregnant males of *S. scovelli* and 177 pregnant males of *S. floridae* collected at Cedar Key. The mean number of eggs carried by males of *S. scovelli* was 55.6 (Table 9), and the mean number carried by males of *S. floridae* was 357.6 (Table 10). The maximum number of eggs in *S. scovelli* was 175, and the maximum in *S. floridae* was 886. The greater number of eggs incubated by males of *S. floridae* results, in part, from the larger adult size of this species. However, a considerably larger mean number of eggs per centimeter of length for *S. floridae* (Tables 9 and 10) indicates that this difference involves more than size. Fertilized eggs of *S. floridae* are slightly smaller than those of *S. scovelli*, but this difference is not sufficient to account for the larger brood sizes. Reproductive activity in *S. floridae*, as indicated by the abundance of pregnant males in the Cedar Key area, is less than in *S. scovelli*. Nevertheless, the larger number of eggs carried by pregnant males of *S. floridae* suggests a greater fecundity than in *S. scovelli*.

Brood counts were made for six pregnant males of *S. louisianae* examined from other Florida localities (Table 11). These six males carried a mean of 664.7 eggs, and the maximum number carried by a single male was 898. These few data show that males of *S. louisianae* carry an even larger number of eggs than *S. floridae*, indicating a high level of fecundity in this species also.

The pregnant male of *M. crinigerus* taken at Cedar Key in this study carried 24 eggs. Nine other pregnant males from various Florida locations carried an average of 21.7 eggs. The maximum number carried by a male of this species was 41.

Previous studies have indicated that males of *S. scovelli* inhabiting fresh water incubate fewer eggs than those found in salt water. Hellier (1967) reported an abnormally low average of 12.2 embryos per pouch for 19 males collected in the Santa Fe River, and McLane (1955) reported an average of 29.5 for 66 males from the St. Johns River. In this study additional brood counts were made for 46 pregnant males from Tampa Bay, 17 from Everglades National Park, and 13 from the Florida Keys. The average numbers of eggs carried by males from these three populations were 41.6, 25.1, and 48.8, respectively. These values overlap the average count reported for the freshwater population in the St. Johns River by McLane (1955). The unusually low average brood count obtained for the Santa Fe River specimens by Hellier (1967) provides additional evidence for the genetic isolation of this population.

Monthly mean numbers of eggs carried by pregnant males of *S. scovelli* at Cedar Key ranged from 15.0 to 101.0 (Table 9), and monthly mean numbers carried by pregnant males of *S. floridae* varied from 240.0 to 585.5 (Table 10). As previously discussed, a part of this variation in monthly means probably results from seasonal changes in the average size of adults in the population. The relationships between standard length and number of eggs carried by pregnant males of *S. scovelli* and *S. floridae* are illustrated in Figures 15 and 16, respectively. These show a general rise in the number of eggs with increasing length, although there is not a straight-line relationship in either species. Variability in this relationship should be expected since the number of eggs carried by a male may reflect the size of his sexual partner as well as his own size.

Mature ova of the pipefishes considered here are bright orange in color, both before and after preservation. This orange coloration results from the presence of many small orange-red oil globules imbedded in the periphery of the yolk (Gudger, 1905). In addition to the orange yolked eggs, other bodies are sometimes contained in the brood pouch of males. These include whitish or translucent pieces of material of various sizes and whitish eggs that are considerably larger than normal. These large abnormal eggs are evidently unfertile since embryological development is not apparent in any of them. These abnormal bodies are much more common in *S. scovelli* than in the other species.

Fertilized eggs of the two smaller species studied, *S. scovelli* and *M. crinigerus*, are slightly larger in size than those of *S. floridae* and *S. louisianae*. Eggs carried in the brood pouches of these two species range from 0.9 to 1.3 mm in diameter, with the average lying between 1.1 and 1.2 mm. Eggs carried by males of *S. floridae* vary from 0.6 to 1.2 mm in diameter, and the average lies in the range of 0.8 to 0.9 mm. Eggs carried by the few males of *S. louisianae* examined in this study were quite variable in size, ranging

Figure 15. Number of eggs plotted against standard length of pregnant males of Syngnathus scovelli collected at Cedar Key, Florida, in June, 1969.

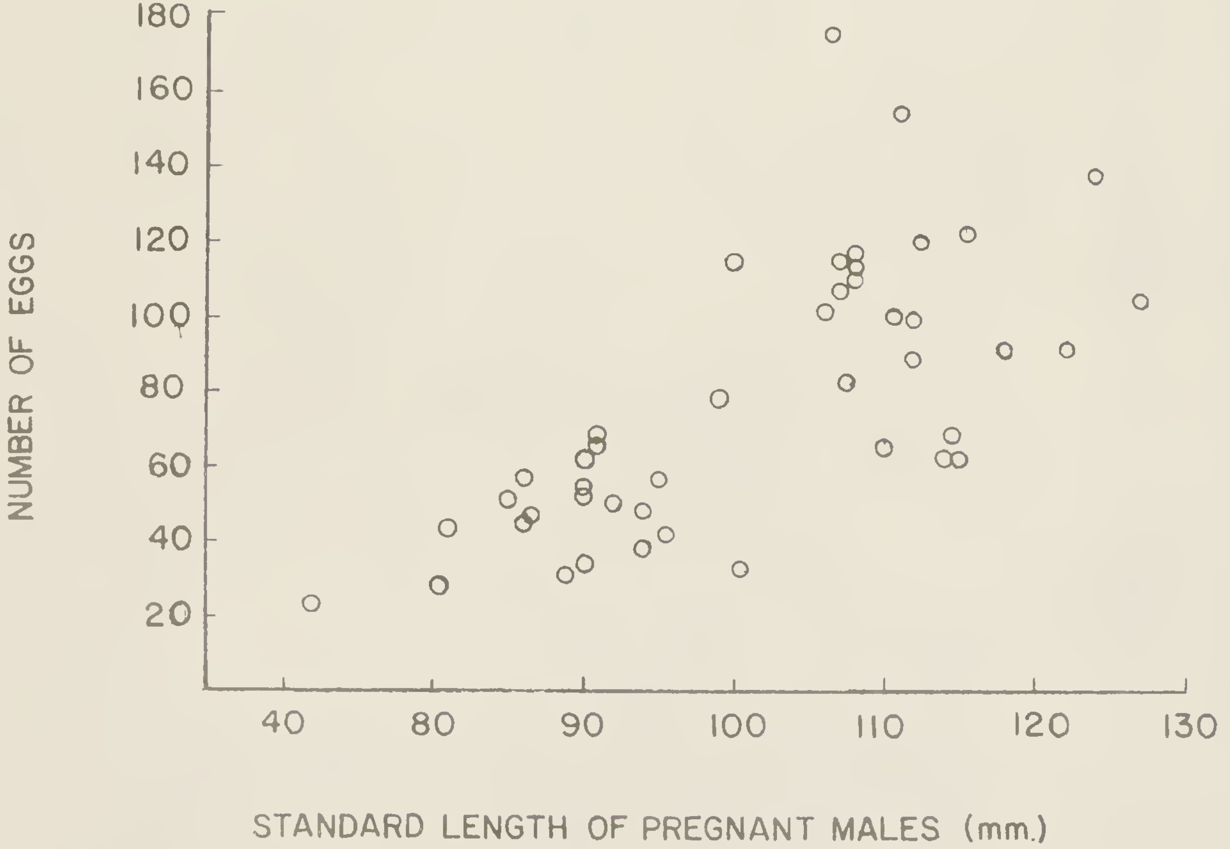
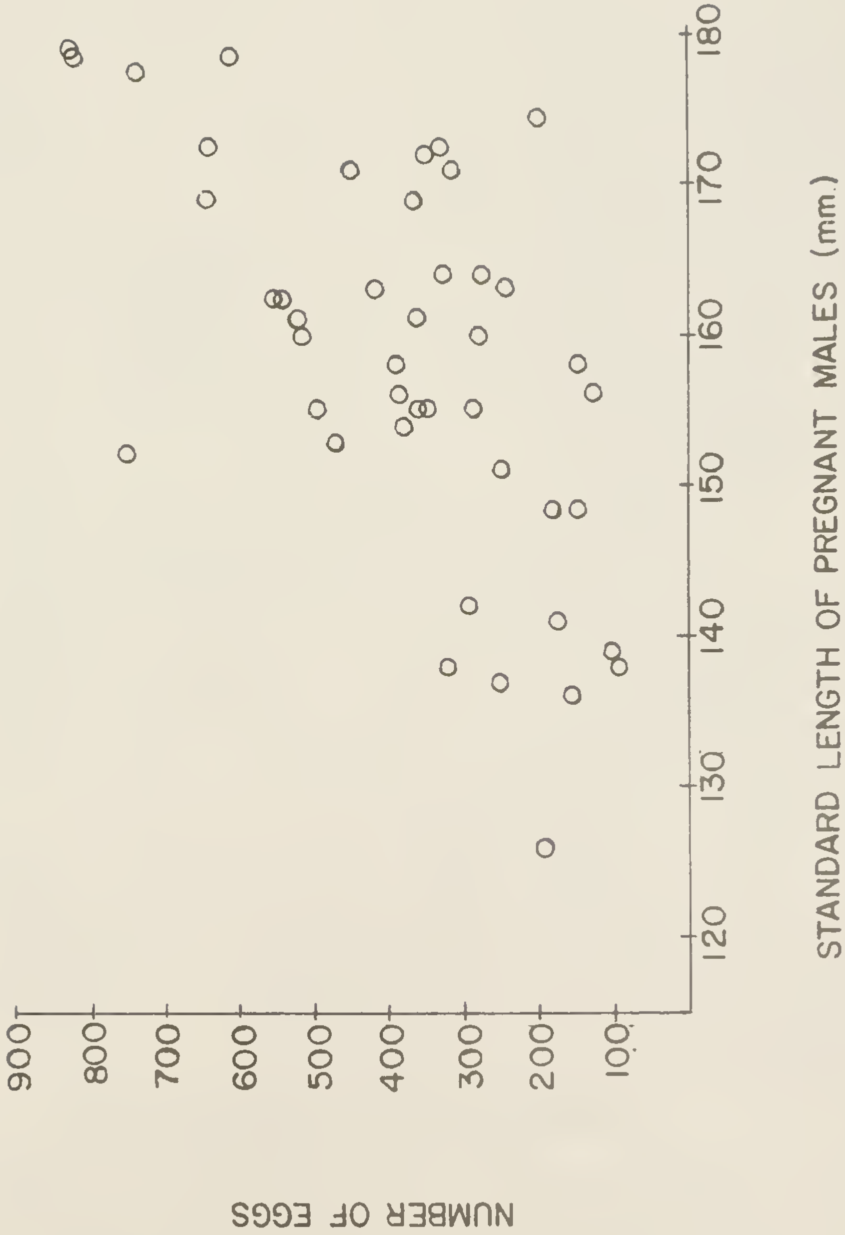

NUMBER OF EGGS
180
160
140
120
100
80
60
40
20
40
80
90
100
110
120
130
STANDARD LENGTH OF PREGNANT MALES (mm.)

Figure 16. Number of eggs plotted against standard length of pregnant males of *Syngnathus floridae* collected at Cedar Key, Florida, in August, 1969.


NUMBER OF EGGS
900
800
700
600
500
400
300
200
100
120
130
140
150
160
170
180
STANDARD LENGTH OF PREGNANT MALES (mm.)

from 0.6 to 1.4 mm in diameter. The average diameter is approximately 1.0 mm.

AGE AND GROWTH

Age and growth of pipefishes in the Cedar Key area were determined by means of the length-frequency analysis. This procedure can be used to trace growth of young during the first year of life and to determine the age composition of a population (Koster, 1955), but it involves certain limitations. Problems result when overlap is present between populations older than two or three years. Also, the lack of distinct breeding seasons, as shown for Cedar Key pipefishes, tends to complicate the analyses of growth during the year. Moreover, most collecting methods involve some degree of selectivity for size, no matter how carefully designed. Collecting gear used in this study was obviously more effective in the capture of larger specimens, resulting in more complete data for sexually mature adults.

Monthly length-frequency distributions in 10 mm intervals of specimens of _S. scovelli_ collected at Cedar Key are given in Figures 17, 18, and 19. Similar distributions for _S. floridae_ are shown in Figures 20, 21, and 22. Adult males and females were combined in these distributions, even though females of both species tend to be slightly larger. The use of 10 mm intervals should eliminate some effects of this size difference. Nevertheless, this variable must be weighed in any conclusion. Inasmuch as collecting efforts were not constant in all months of the study (Table 8), it is necessary to compare the relative frequencies of size classes rather than absolute numbers.

Figure 17. Length-frequency distributions of *Syngnathus scovelli* collected at Cedar Key, Florida, from September, 1968, to June, 1969.

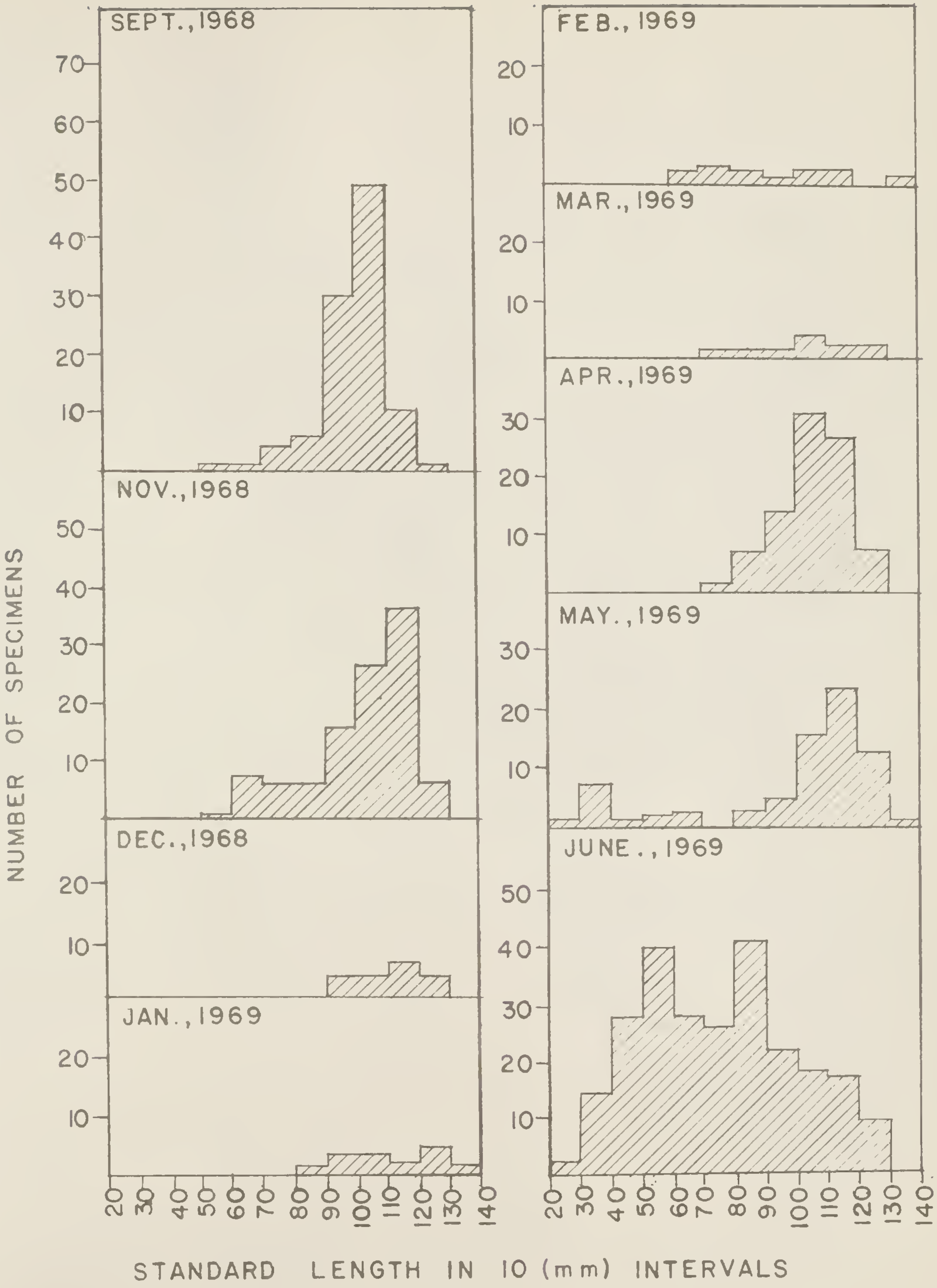

SEPT., 1968
NOV., 1968
DEC., 1968
JAN., 1969
FEB., 1969
MAR., 1969
APR., 1969
MAY., 1969
JUNE., 1969
NUMBER OF SPECIMENS
10
20
30
40
50
60
70
20
30
40
50
60
70
80
90
100
110
120
130
140
STANDARD LENGTH IN 10 (mm) INTERVALS

Figure 18. Length-frequency distributions of *Syngnathus scovelli* collected at Cedar Key, Florida, in July and August, 1969.

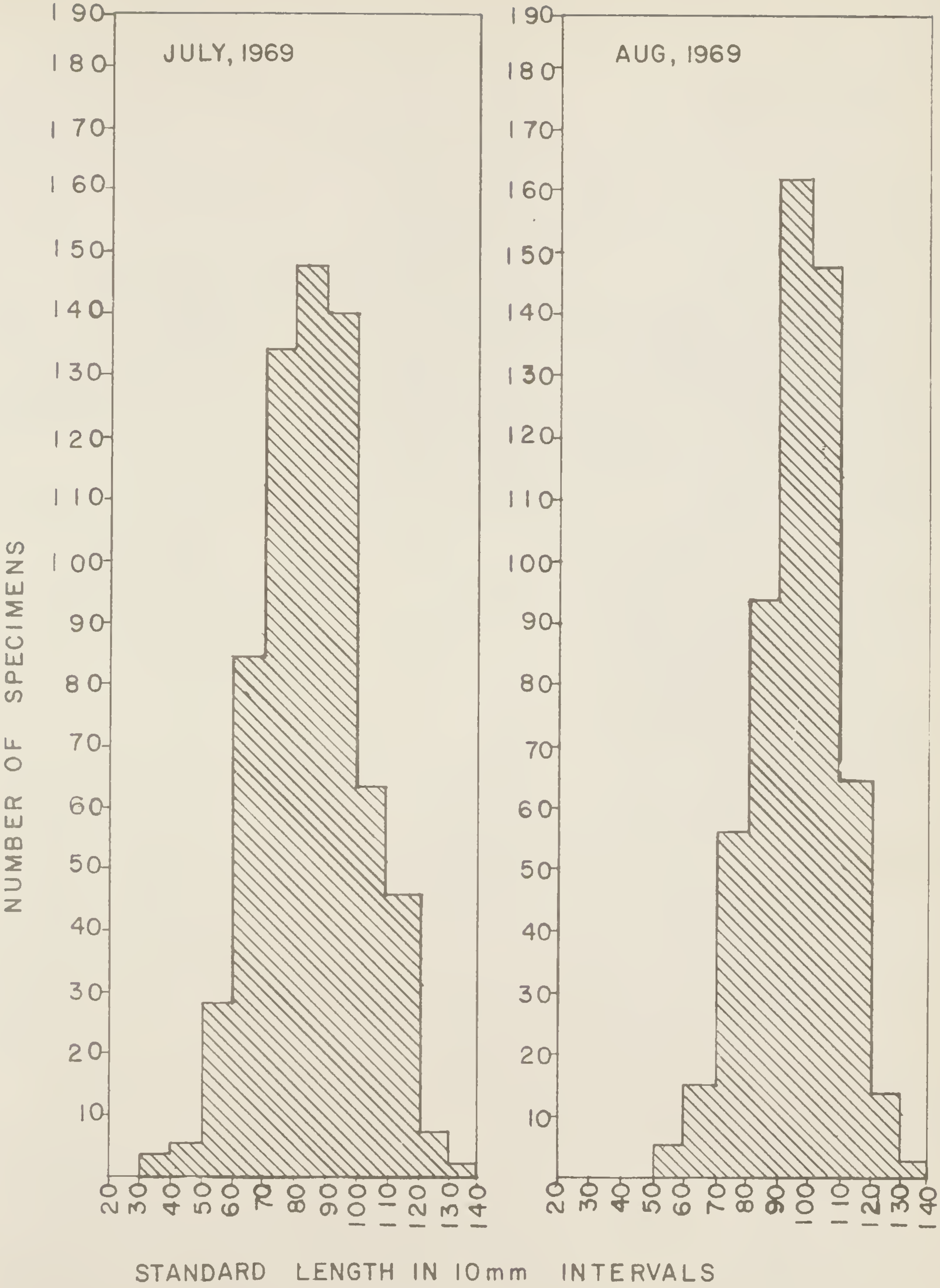

JULY, 1969
AUG, 1969
NUMBER OF SPECIMENS
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
20
30
40
50
60
70
80
90
100
110
120
130
140
STANDARD LENGTH IN 10mm INTERVALS

Figure 19. Length-frequency distributions of *Syngnathus scovelli* collected at Cedar Key, Florida, from September to December, 1969.

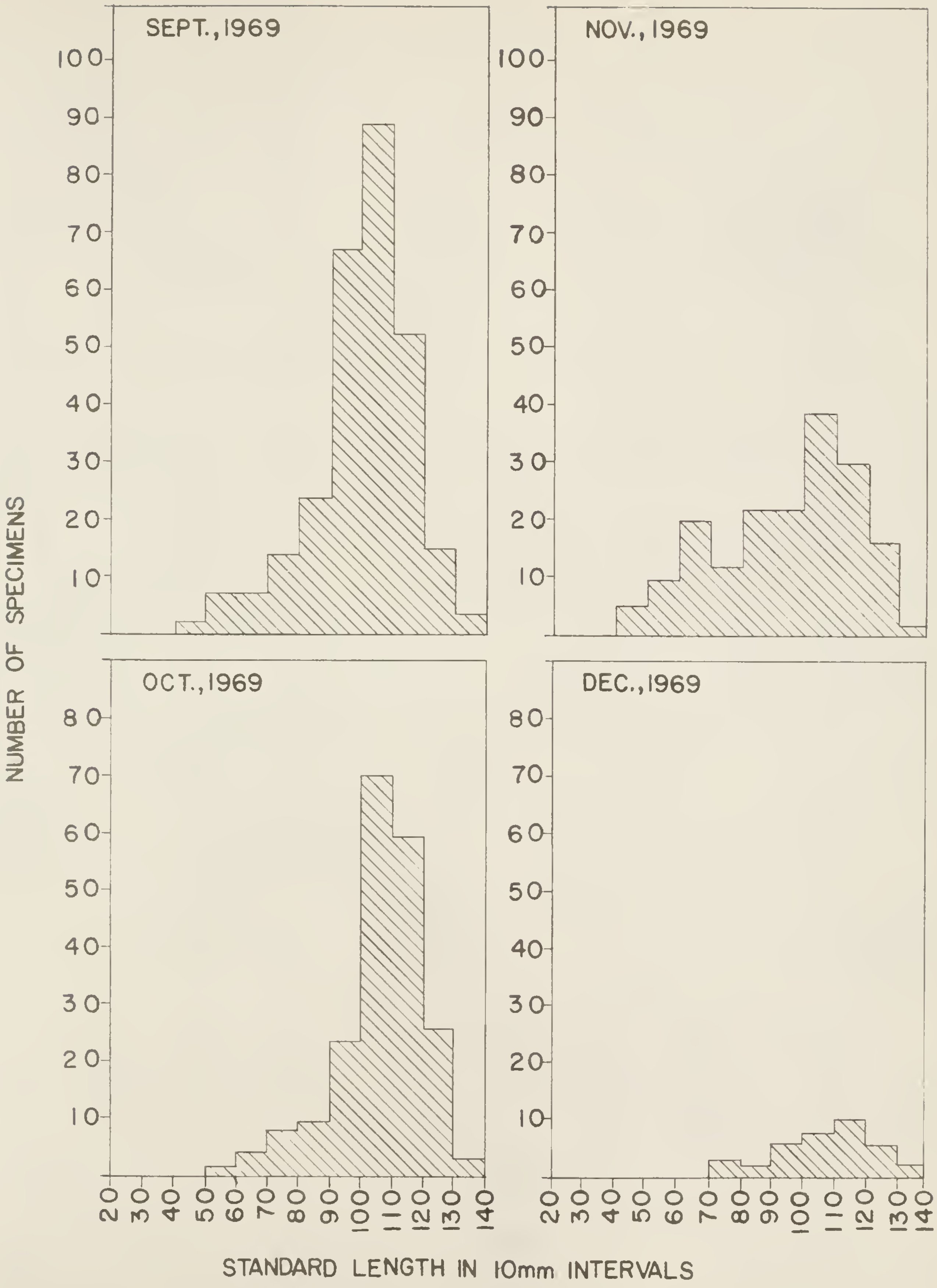

SEPT., 1969
NOV., 1969
OCT., 1969
DEC., 1969
NUMBER OF SPECIMENS
10
20
30
40
50
60
70
80
90
100
20
30
40
50
60
70
80
90
100
110
120
130
140
STANDARD LENGTH IN 10mm INTERVALS

Figure 20. Length-frequency distributions of *Syngnathus floridae* collected at Cedar Key, Florida, from September, 1968, to April, 1969.

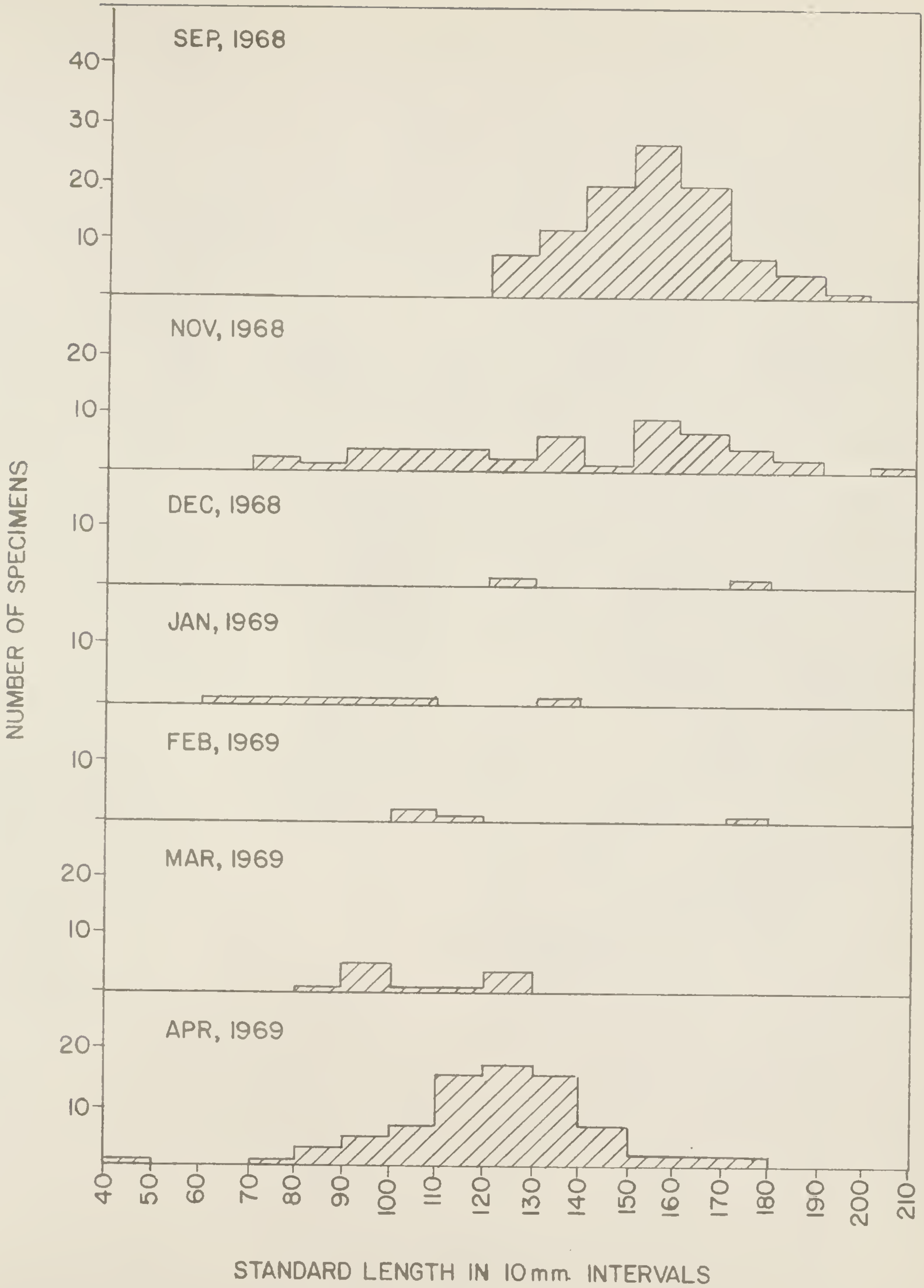

SEP, 1968
NOV, 1968
DEC, 1968
JAN, 1969
FEB, 1969
MAR, 1969
APR, 1969
40
30
20
10
NUMBER OF SPECIMENS
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
STANDARD LENGTH IN 10mm INTERVALS

Figure 21. Length-frequency distributions of *Syngnathus floridae* collected at Cedar Key, Florida, from May to August, 1969.

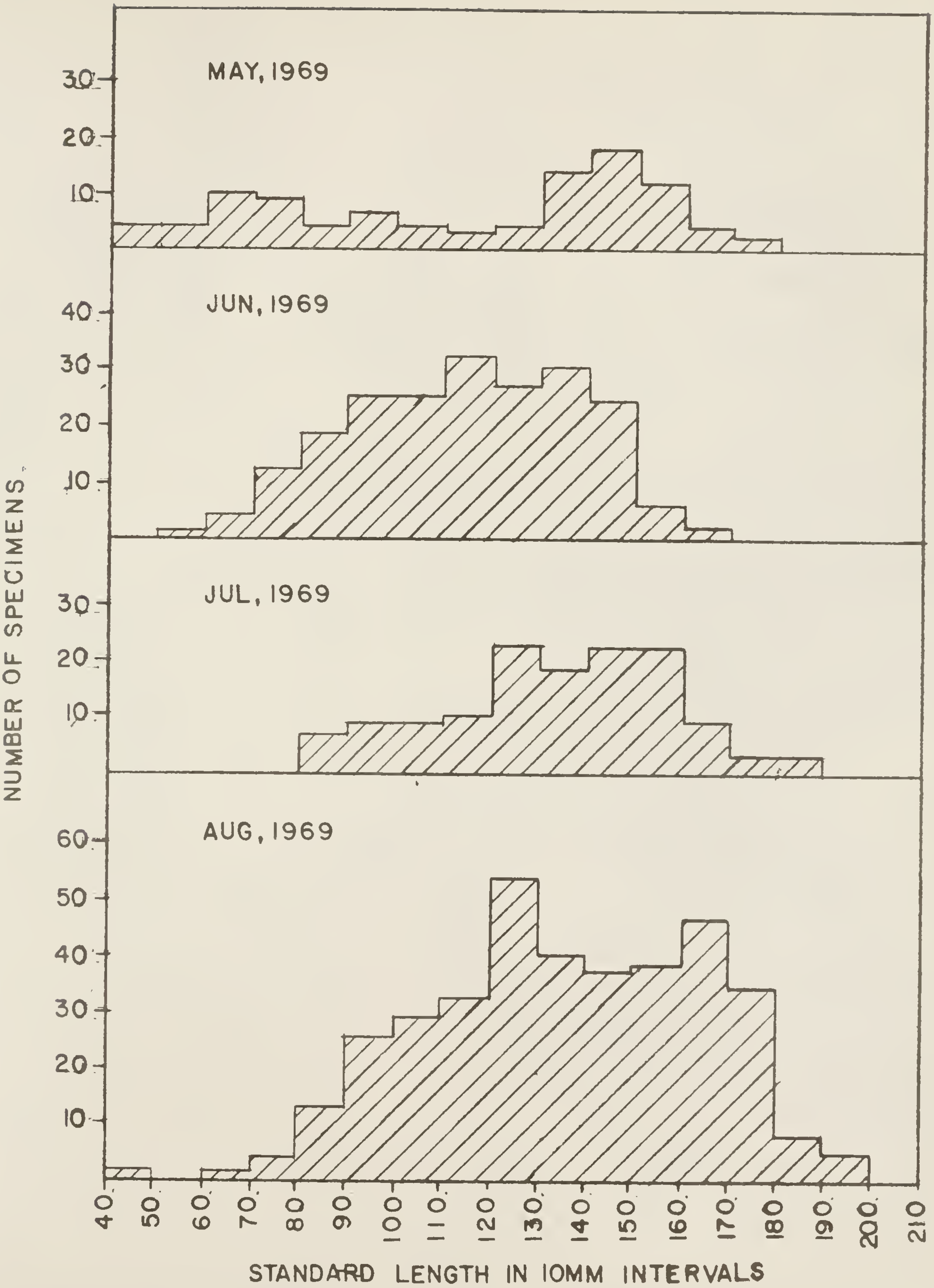
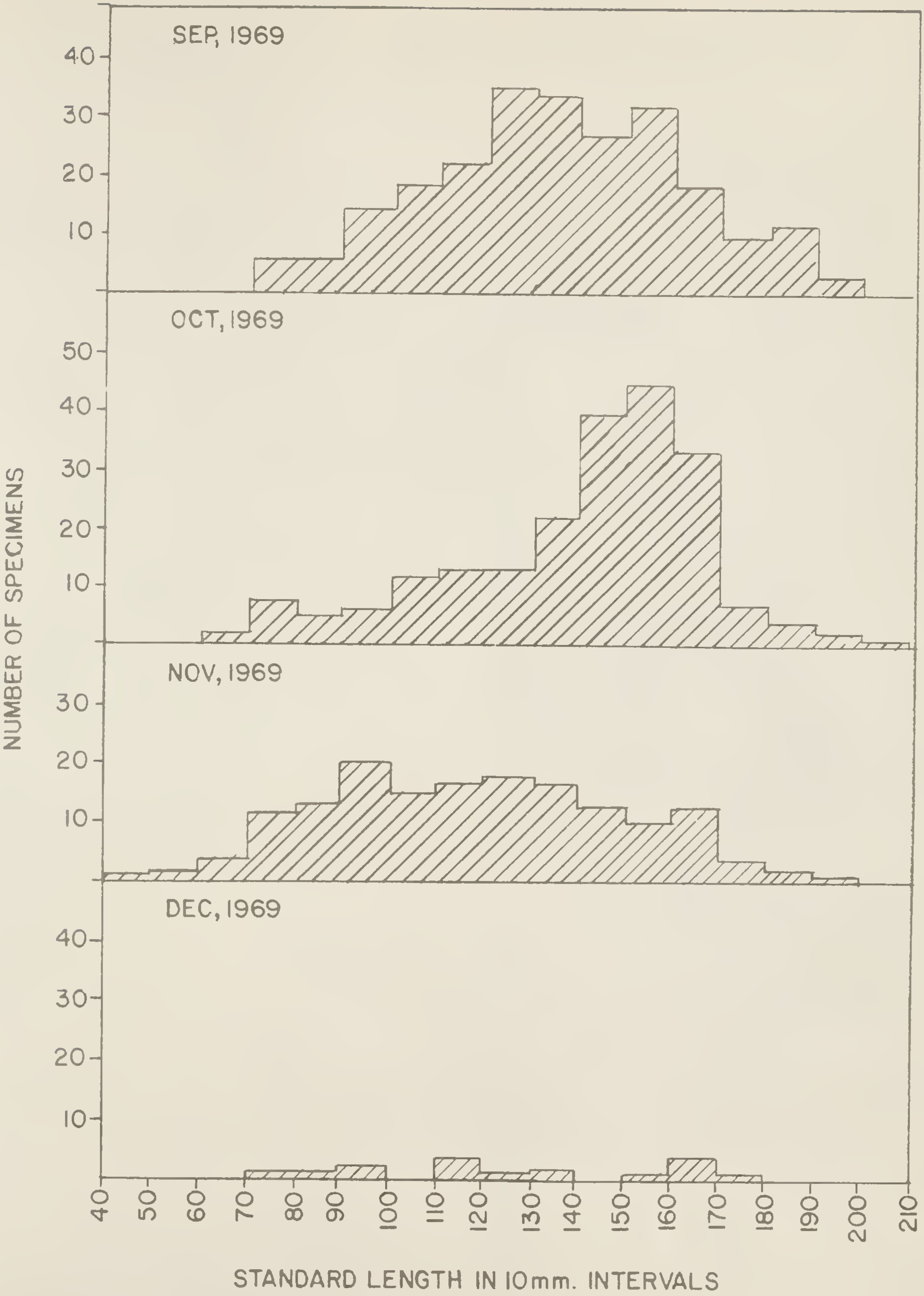

MAY, 1969
JUN, 1969
JUL, 1969
AUG, 1969
NUMBER OF SPECIMENS
10
20
30
40
50
60
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
STANDARD LENGTH IN 10MM INTERVALS

Figure 22. Length-frequency distributions of *Syngnathus floridae* collected at Cedar Key, Florida, from September to December, 1969.


SEP, 1969
40
30
20
10
OCT, 1969
50
40
30
20
10
NOV, 1969
30
20
10
DEC, 1969
40
30
20
10
NUMBER OF SPECIMENS
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210
STANDARD LENGTH IN 10mm. INTERVALS

The distributions show that maximum length in the Cedar Key area lies in the 130-140 mm size range for S. scovelli and in the 200-210 mm range for S. floridae. Individuals of these sizes are never abundant, and they are nearly all females. The smallest specimens collected were in the 20-30 mm interval for S. scovelli and in the 40-50 mm interval for S. floridae. The small number of these immature forms captured and the failure to obtain even smaller individuals undoubtedly resulted from the selectivity of the collecting equipment, although it seems that immature specimens of S. floridae smaller than 40 mm in length would have been taken. Size at birth is about 15 mm for S. scovelli and 11 mm for S. floridae. Hence, smaller individuals than those taken in this study must be quite abundant at certain times.

Distributions for S. scovelli show that in the months of January, February, and March only a few individuals, mostly in the 90-130 mm size range, are present. Since members of S. scovelli usually attain sexual maturity by the time they reach 100 mm in length, these specimens represent sexually mature fish for the most part. During April and May there is a concentration of adults in the 100-130 mm range. The obvious increase in numbers in these months results, in part, from increased collecting efforts; but fish actually become more abundant, as demonstrated by an increased average number per collection (Table 8). These are individuals that overwintered in the Cedar Key area. The possible dispersal of these fish to deeper areas during cold winter months when the flats are nearly devoid of vegetation might explain their decline in collections made during this period. Grass reappears in April, and pipefish once again move onto the flats.

April and May represent a peak period of reproduction for S. scovelli (Table 9). Many young fish, too small for capture, are probably present in April. Later these young, in the 20-70 mm range, appear in May collections. Furthermore, this sizable spring spawn is illustrated by the large class of fish in the 40-100 mm range present in June. This group grows rapidly during summer months, and by September and October the flats are populated by a large mass of sexually mature individuals. The fish in the 100-130 mm range present in early spring seem to decline in importance during June, July, and August, suggesting that these individuals may not live through the summer. Strawn (1958) observed that overwintering Cedar Key H. zosterae disappeared from the flats by August of the following summer.

October and November are also months of extensive reproductive activity for S. scovelli, but only limited numbers of the fall young appear in collections made in succeeding months. Their absence in collections made during these months may result from a reduction in the survival of these fish caused by winter conditions and the dispersal of the remaining young into deeper water. In spring these fish, having grown to sexual maturity during winter, become concentrated on the flats and are responsible for spring reproduction. A second possible explanation for their absence is that few or none of the fall young survive until spring. Thus, spring spawners are actually adults that survived from the preceding fall. Both of these explanations are probably correct, in part, since S. scovelli breeds continually in the Cedar Key region.

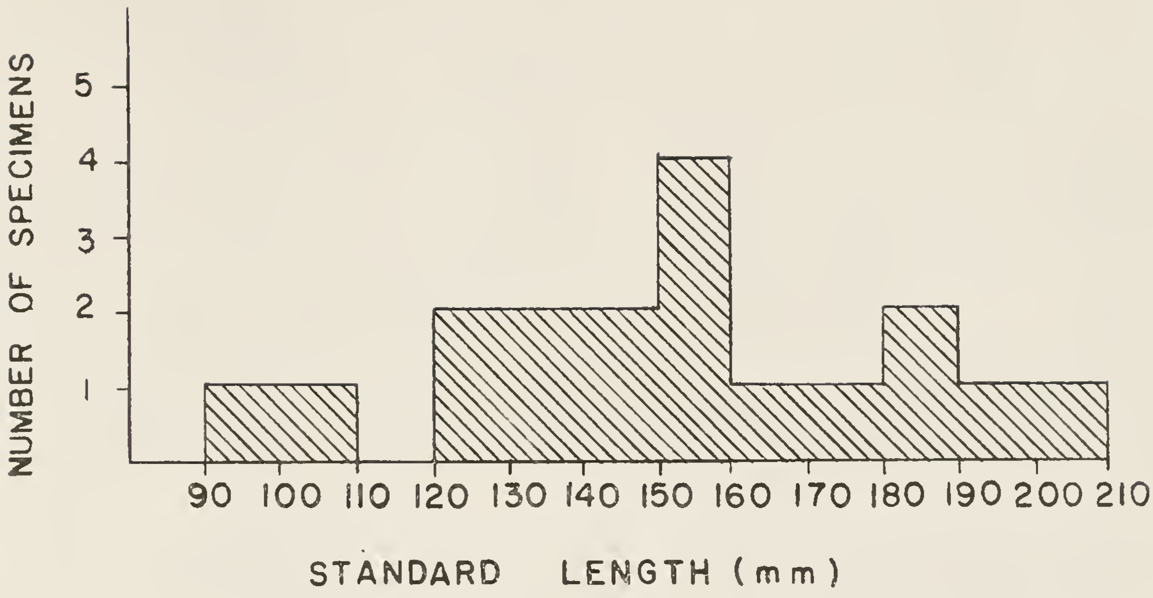
These results indicate that members of S. scovelli reach maturity and reproduce in less than one year, and apparently few survive beyond this first year. This agrees with Joseph's (1957) results which suggest a short life cycle with an age at sexual maturity of approximately six months. Individuals born in April and May grow to a size of 90 to 120 mm by September and are responsible for the fall spawn. Young born in fall probably survive in limited numbers in order to form part or all of the smaller breeding population present in spring. These patterns tend to be somewhat obscured by the continuous breeding habit of *S. scovelli* in this area.

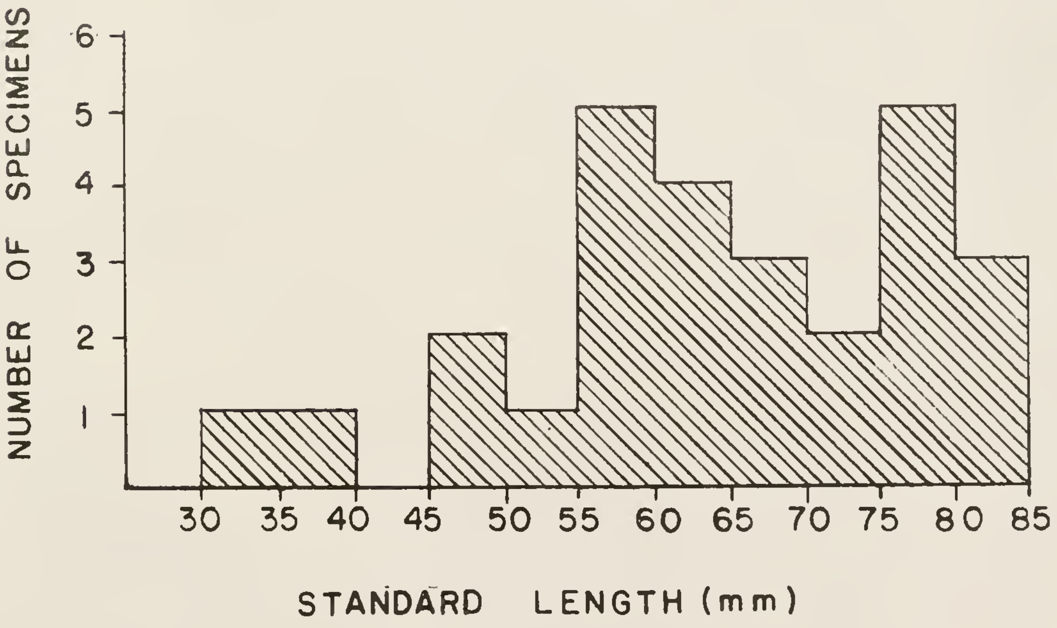
The pattern of age and growth in *S. floridae* is very much like that in *S. scovelli*. Apparently most individuals achieve sexual maturity and die in less than one year. Few specimens are present during January, February, and March; and most of those present are immatures of less than 130 mm in length, as illustrated by the decline in reproductive activity during this time (Table 10). By May this group has grown to the 130-160 mm size range at which sexual maturity is reached. Small immature fish of less than 120 mm in length appear in May and June. By August many of these exceed 130 mm in length. In October these make up a large adult class in the 140-170 mm range that is responsible for fall reproduction. This large group seems to die or disperse during the months of November, December, and January; and these fish never reappear on the flats. Smaller individuals present during winter months were probably born in fall, and this group forms the breeding population of the following spring. As in *S. scovelli*, the pattern is somewhat obscure as a result of nearly continuous breeding.

Collections of *S. louisianae* and *M. crinigerus* are obviously too few in number to make detailed analyses of age and growth. However, it seems probable that patterns of age and growth in these species are similar to those of *S. scovelli* and *S. floridae*. The larger adult size achieved by *S. louisianae* might indicate a longer life cycle, but there is no empirical data available to support this. Length-frequency distributions of all specimens of *S. louisianae* and *M. crinigerus* collected at Cedar Key are shown in Figures 23 and 24, respectively.

Figure 23. Length-frequency distribution of *Syngnathus louisianae* collected at Cedar Key, Florida, from September, 1968, to December, 1969.

Figure 24. Length-frequency distribution of *Micrognathus crinigerus* collected at Cedar Key, Florida, from September, 1968, to December, 1969.


NUMBER OF SPECIMENS
5
4
3
2
1
90
100
110
120
130
140
150
160
170
180
190
200
210
STANDARD LENGTH (mm)


NUMBER OF SPECIMENS
6
5
4
3
2
1
30
35
40
45
50
55
60
65
70
75
80
85
STANDARD LENGTH (mm)

FOOD

Feeding habits of pipefishes are largely influenced by anatomical specializations of the group. The simple digestive tract is straight and without caeca, making it best suited for a strictly carnivorous diet; and the small mouth positioned at the terminal end of the tubular snout restricts food items to tiny organisms that can be drawn in by suction. Grass flats inhabited by pipefishes are rich with micro-crustaceans, and they comprise the main food supply of this group of fishes (Reid, 1954; Springer and Woodburn, 1960).

The stomach contents of 150 specimens of _S. scovelli_, 140 _S. floridae_, 18 _S. louisianae_, and 27 _M. crinigerus_ collected at Cedar Key were examined. The frequency of occurrence of each type of organism and the number of individual organisms in each stomach were recorded. Results were analyzed according to season of the year and to sizes of the individuals from which stomach contents were taken.

Food items utilized by _S. scovelli_ during each season of 1969 are given in Table 14. Specimens examined for each season include individuals of various sizes. All specimens of this species examined are grouped into three size classes, and the food of each class is shown in Table 15. Food of _S. floridae_ is treated similarly in Tables 16 and 17.

Some 91.3% of the stomachs of _S. scovelli_ and 94.3% of those of _S. floridae_ contained food. The only noticeable seasonal change in

Table 14. Food of 150 Specimens of *Syngnathus scovelli* Collected in the Cedar Key, Florida, Area in 1969 Analyzed According to Season.

	Winter			Spring			Summer			Fall					
Stomachs, examined with food	30 20			40 40			40 37			40 40			Total Stomachs with Food		
Food Item	No.[a]	%[b]	Per Stomach[c]	No.	%	Per Stomach	No.	%	Per Stomach	No.	%	Per Stomach	No.	%	Per Stomach
Shrimp and/or Mysids	3	15.0	3.7	9	22.5	3.5	17	45.9	5.2	14	35.0	3.8	43	31.4	4.2
Amphipods	17	85.0	3.8	38	95.0	11.7	26	70.3	4.4	38	95.0	5.7	119	86.9	7.1
Copepods	12	60.0	5.4	26	65.0	11.2	14	37.8	24.2	32	80.0	16.3	84	61.3	14.5
Isopods	3	15.0	2.7	12	30.0	2.3	6	16.2	1.2	2	5.0	1.0	23	16.8	2.0
Ostracods				10	25.0	29.6	12	32.4	14.6	15	37.5	8.7	37	27.0	16.3
Larval Decapods							1	2.7	1.0				1	0.7	1.0
Larval *Syngnathus* sp.							1	2.7	1.0	1	2.5	1.0	2	1.5	1.0

[a] Number of stomachs containing each type of food organism.
[b] Percentage of stomachs with food containing each type of food organism.
[c] Average number of each type of food organism per stomach.

Table 15. Food of 150 Specimens of Syngnathus scovelli Collected in the Cedar Key, Florida, Area in 1969 Analyzed According to Size.*

	Standard Length (mm)								
	37.5-70.0			71.5-98.0			104.5-133.0		
Stomachs, examined	33			52			65		
with food	31			48			58		
Food Item	No.	%	Avg. No. Per Stomach	No.	%	Avg. No. Per Stomach	No.	%	Avg. No. Per Stomach
Shrimp and/or Mysids	2	6.5	1.0	8	18.8	1.2	33	56.9	5.3
Amphipods	21	67.7	3.4	43	89.6	6.8	55	94.8	8.7
Copepods	30	96.8	22.3	33	68.8	13.8	21	36.2	4.4
Isopods	2	6.5	1.0	11	22.9	2.7	10	17.2	1.3
Ostracods	5	16.1	7.7	17	35.4	17.8	15	25.9	17.3
Larval Decapods				1	2.1	1.0			
Larval Syngnathus sp.							2	3.4	1.5

*Data presented same as in Table 14.

Table 16. Food of 140 Specimens of *Syngnathus floridae* Collected in the Cedar Key, Florida, Area in 1969 Analyzed According to Season.*

	Winter			Spring			Summer			Fall					
Stomachs, examined with food	20 18			40 36			40 40			40 38			Total Stomachs with Food		
Food Item	No.	%	Per Stomach	No.	%	Per Stomach	No.	%	Per Stomach	No.	%	Per Stomach	No.	%	Per Stomach
Shrimp and/or Mysids	10	55.6	2.5	24	66.7	5.2	38	95.0	2.6	32	84.2	3.3	104	78.8	3.4
Amphipods	9	50.0	1.8	12	33.3	2.0	17	42.5	1.8	21	55.3	2.1	59	44.7	1.9
Copepods	8	44.4	1.0	18	50.0	9.4	10	25.0	1.6	10	26.3	3.2	46	34.8	4.9
Isopods	1	5.6	1.0				4	10.0	1.0	2	5.3	1.0	7	5.3	1.0
Ostracods	4	22.2	9.0	2	5.6	21.0				7	18.4	11.8	13	9.8	12.4
Larval Decapods							1	2.5	1.0	1	2.5	1.0	2	1.5	1.0
Larval *Syngnathus* sp.										1	2.6	2.0	1	0.8	2.0

*Data presented same as in Table 14.

Table 17. Food of 140 Specimens of *Syngnathus floridae* Collected in the Cedar Key, Florida, Area in 1969 Analyzed According to Size.*

	Standard Length (mm)								
	51.0-90.0			92.5-129.0			135.0-181.0		
Stomachs, examined	36			49			55		
with food	32			47			53		
Food Item	No.	%	Avg. No. Per Stomach	No.	%	Avg. No. Per Stomach	No.	%	Avg. No. Per Stomach
Shrimp and/or Mysids	15	46.9	1.6	38	80.9	2.7	51	96.2	4.5
Amphipods	17	53.1	2.2	20	42.6	1.9	22	41.5	1.8
Copepods	22	68.8	8.8	17	36.2	1.5	7	13.2	1.0
Isopods				3	6.4	1.0	4	7.5	1.0
Ostracods	3	9.4	15.0	3	6.4	11.0	7	13.2	11.8
Larval Decapods				2	4.3	1.0			
Larval *Syngnathus* sp.							1	1.9	2.0

*Data presented same as in Table 14.

feeding level occurred during winter in *S. scovelli*, when 20 of 30 stomachs contained food organisms (Table 14). Other apparent seasonal variations in feeding included a slight increase in the variety of food organisms eaten in summer and fall by both species, an increase in the frequency of utilization of small shrimp in summer and fall by both *S. scovelli* and *S. floridae*, a summer and fall increase in the consumption of copepods by *S. scovelli*, and a summer and fall decrease in the frequency with which copepods were taken by *S. floridae* and with which ostracods were taken by *S. scovelli* (Tables 14 and 16).

The diet of these two pipefishes consists almost entirely of microcrustaceans. Organisms taken most often by *S. scovelli* are amphipods, but copepods and small shrimp are also frequently utilized (Table 14). An individual stomach may contain more than 50 copepods; however, these organisms often constitute a minor part of the volume of stomach contents because of the much greater size of amphipods and shrimp. Isopods and ostracods occur less frequently in the diet of *S. scovelli*, but ostracods may form the bulk of the stomach contents of occasional individuals.

The food of *S. scovelli* changes according to stages in its life cycle (Table 15). Immature fish of less than 70 mm in length feed primarily on copepods, with small amphipods being taken somewhat less frequently. Fish in the 70-100 mm size range show a transition in diet from planktonic forms to organisms living on the sea grasses. Amphipods and small shrimp increase in both frequency of occurrence and numbers per stomach in larger individuals. Amphipods are the most frequently eaten food item by adults over 100 mm in length. The various shrimps are too large for immature fish, but they form a substantial part of the diet of larger adults. Because of the greater mass of shrimp, they often make up most of the volume of stomach contents, although only a few specimens are usually present in a single stomach. The utilization of copepods declines considerably in adults. Conversely, ostracods seem to increase in importance in the diet of larger fish.

In fresh water the food of *S. scovelli* is altered slightly, but the nature of the diet is essentially the same as in salt water. In addition to freshwater shrimp, amphipods, and copepods, freshwater members of this species eat cladocerans, chironomid larvae, and mosquito larvae (McLane, 1955; Whatley, 1969).

S. floridae eats the same material as *S. scovelli*, but the various organisms differ in relative importance (Table 16). Small shrimp are the most frequently utilized food item. Amphipods and copepods are also taken often, but these organisms do not assume the importance in the diet of this species that they do in *S. scovelli*. Isopods and ostracods are eaten occasionally.

Analysis of the food of *S. floridae* according to size shows definite changes in diet with increasing length, but the changes are not as pronounced as in *S. scovelli* (Table 17). Immature individuals of less than 90 mm in length rely quite heavily on small shrimp. The utilization of shrimp increases until they form the bulk of the diet of adults in terms of both frequency and volume. Amphipods are taken about equally by all sizes. Dependence upon copepods decreases in adults, but they are never taken as frequently by any size fish of this species as in *S. scovelli*.

Both *S. scovelli* and *S. floridae* exhibit cannibalism (Tables 14-17). Larval pipefishes in advanced stages of digestion occurred in stomachs of adult males of both species. The rarity of these items in stomach contents indicates that cannibalism is not a dominant feature of the feeding habits of these fishes.

Food items of *S. louisianae* and *M. crinigerus* are given in Table 18. Since only a few specimens were available, the data are not treated according to season and size. Small shrimp and amphipods are the most frequently utilized food organisms by *S. louisianae*. Shrimp comprise the bulk of the diet because of their greater mass. Copepods and isopods are also taken occasionally by this large species.

Food organisms taken by *M. crinigerus* reflect the diminutive size of this species. These fish rely primarily on copepods, as do small *S. scovelli*. Tiny amphipods are also quite important and may constitute the main bulk of the stomach contents in many individuals. Isopods and ostracods appear occasionally in stomach contents. Shrimp are rather large for the small mouth of *M. crinigerus*; thus they are seldom eaten by this species.

All four pipefishes utilize the same food organisms; however, there are differences among the diets of these species that may reduce competition for food items. During a large part of the life of an individual *S. scovelli*, copepods and amphipods are the main items eaten. Only the adults of *S. scovelli* assume a diet of small shrimp and amphipods very similar to the diet of *S. floridae* at nearly all sizes. The food of large *S. louisianae* is also quite similar to that

Table 18. Food of 18 Specimens of *Syngnathus louisianae* and 27 Specimens of *Micrognathus crinigerus* Collected in the Cedar Key, Florida, Area in 1969.*

	S. louisianae			*M. crinigerus*		
Food Item	No.	%	Avg. No. Per Stomach	No.	%	Avg. No. Per Stomach
Shrimp and/or Mysids	14	77.8	4.1	2	7.4	1.0
Amphipods	14	77.8	4.6	18	66.7	3.1
Copepods	9	50.0	49.0	26	96.3	13.6
Isopods	7	38.9	1.0	12	44.4	3.7
Ostracods	1	5.6	225.0	4	14.8	5.0

*Data presented same as in Table 14.

of *S. floridae*, but the sparse population of this species on the grass flats does not present substantial competition to *S. floridae* for food. The diminutive *M. crinigerus* exhibits a diet almost indentical to that of juveniles of *S. scovelli*, but adults of *S. scovelli* assume a much different diet. Factors other than size that may affect food selection include the association of food organisms with various sea grasses where the different pipefishes live, the relative ability of these fishes to catch food organisms, and differences in mouth parts, such as snout length. The grass flats where pipefishes occur support a diverse assemblage of larval and juvenile fishes during a large part of the year, and many of them utilize the same microcrustaceans as do pipefishes.

RÉSUMÉ OF AUTHOR'S FINDINGS

A brief account of new information obtained in this study on the life history of these four species of pipefishes is presented here. Each species is treated individually in contrast to the comparative discussion used elsewhere in this paper.

Syngnathus scovelli (Gulf Pipefish)

Sexual dimorphism and geographical variation in morphology are exhibited by *S. scovelli*. Females tend to have slightly longer trunks than males. On the other hand, males tend to possess a greater number of dorsal fin rays. Geographical variation in morphology is possibly associated with temperature and salinity. Both dorsal fin rays and tail rings increase in northward areas in Florida, suggesting a clinal pattern of variation. Head length/snout length ratio decreases in northern and freshwater populations, suggesting that both colder temperature and decreased salinity result in the development of a longer snout. Trunk rings and pectoral fin rays exhibit little variation. Trunk length/tail length ratio is quite variable, but a geographical pattern is not evident.

Morphologically, the freshwater population in the Santa Fe River is the most distinct, suggesting that this population is genetically isolated from saltwater populations in the Gulf of Mexico. The freshwater population in the upper St. Johns River varies little from coastal populations, indicating that genetic exchange occurs between it and populations on the Atlantic coast of Florida.

S. scovelli is the most abundant pipefish in the Cedar Key area. It is found on the grass flats during all months of the year. Its abundance declines considerably in winter, suggesting a possible dispersal into deeper waters; however, collections made in ship channels and deeper inshore areas yielded no specimens during this time.

This species attains sexual maturity over a wide size range. Sexual maturity in the male is revealed by a completely developed brood pounch. It is indicated in the female by ripe ova in the body cavity. The male's brood pouch first appears as a pair of fleshy ridges radiating posteriorly from the vent. These ridges grow medially until they meet, forming the enclosed pouch. This process occurs in males between 60 and 100 mm in length. Sexually mature males vary considerably in size, but most adult males exceed 90 mm in length. Females mature at a larger size than males. Ovarian development is not evident in females less than 80 mm in length, and most mature females exceed 100 mm in length.

The Gulf pipefish breeds continually in the Cedar Key area, but seasonal peaks are indicated. Pregnant males and ripe females occur on the flats during every month of the year. The percentage of adult males incubating eggs and the average number of eggs per centimeter of standard length are greatest in spring and fall, indicating that reproductive activity peaks during these seasons.

Sex ratio varies considerably in this species, but seasonal patterns are evident. At Cedar Key adult females slightly outnumbered adult males in winter and early spring when the population was at a low level. Adult males significantly exceeded adult females in abundance in every month from June through October, 1969, except August. The smaller size at which males mature probably accounts for their numerical superiority during summer. Many large immature females were present during this time, and sex ratio reversed later in fall when these fish achieved maturity.

Fertilized eggs are arranged in two to eight rows in the brood pouch, lying both side-by-side and on top of one another. Brood counts made for 346 pregnant males from Cedar Key yielded a mean of 55.6 eggs per pouch. The maximum was 175. Generally, the number of eggs incubated by pregnant males varies with the size of the male. Fertilized eggs range from 0.9 to 1.3 mm in diameter, with the average lying between 1.1 and 1.2 mm. The yolk sac is absorbed before birth, and young measure about 15 mm at birth.

Length-frequency distributions show that maximum length achieved by S. scovelli in the Cedar Key area lies in the 130 to 140 mm size range. These larger fish are nearly all females. The size distributions demonstrate a concentration of adults on the grass flats in spring. These large adults disappear by late summer, and immature fish born in spring constitute the bulk of the population present in summer. The large group of young present in summer grow to maturity and breed in fall. Survival of young produced in fall is apparently reduced by winter conditions, but a limited number overwinter and form the breeding population of the following spring. These results indicate that this species grows to maturity and breeds within a year of birth. Few individuals apparently survive beyond this first year.

Amphipods are the most often utilized food item by *S. scovelli*, but copepods, small shrimp, and mysids are also frequently taken. Isopods, ostracods, larval decapods, and larval pipefishes are less important items included in the diet of this species. Seasonal variations in feeding include a slight increase in the variety of food organisms eaten in summer and fall, a summer and fall increase in the consumption of small shrimp and copepods, and a summer and fall decrease in the utilization of ostracods. The relative importance of the various food organisms changes according to stages in the life cycle of *S. scovelli*. Immature fish of less than 70 mm feed mainly on copepods, with amphipods taken less frequently. Fish in the 70 to 100 mm range show a shift toward a diet of amphipods and small shrimp. Adults over 100 mm feed mainly on amphipods and small shrimp. The utilization of copepods declines considerably in adults.

Syngnathus floridae (Dusky Pipefish)

Sexual dimorphism is demonstrated by *S. floridae*. Adult females exceeding 150 mm in length exhibit a greater body depth than males, but this character is obscure in smaller females. Furthermore, females tend to have longer trunk and head lengths, but males possess a larger number of dorsal fin rays. No geographical variation in morphology was indicated between populations from Cedar Key and Alligator Harbor. These populations represent similar habitats, which may account for their uniformity in morphology.

The dusky pipefish is the second most abundant pipefish at Cedar Key, occurring on the grass flats during every month of the year. Its abundance greatly declines in winter, but its absence in deep-water collections made in winter suggests there is no dispersal into deeper inshore areas.

Sexual maturity in this species is indicated by the same characters as in S. scovelli. Similarly, sexual maturity is achieved over a wide range of sizes. The brood pouch in various developmental stages occurs in males ranging from 100 to 160 mm in length. Most males mature by the time they reach the 140 to 150 mm size range. Females in the 120 to 140 mm range usually exhibit some ovarian development, although females of this size with no ovarian development are not rare. Most females larger than 140 mm in length are sexually mature.

Reproduction is an almost continual process in S. floridae. At Cedar Key pregnant males were encountered in all months of the year except December through February. Ripe females occurred in every month except December. The percentage of adult males incubating eggs and the average number of eggs per centimeter of standard length indicate that reproductive activity peaks in spring and fall. Reproductive activity is at a low level in winter at Cedar Key as indicated by the absence of pregnant males.

Sex ratio varies in *S. floridae*, but it is much less erratic than in *S. scovelli*. At Cedar Key mature females outnumbered mature males in every month except one when the sexes were equal in abundance. Adult females were over twice as numerous as adult males in fall and winter, but they exceeded males only slightly in summer.

Fertilized eggs lie in four to sixteen rows in the brood pouch of *S. floridae*. The mean number of eggs carried by 177 pregnant males from Cedar Key was 357.6, and the maximum was 886. The number of eggs incubated by pregnant males depends largely upon the size of the male. The relative difference in the number of eggs incubated by males of *S. floridae* as compared to *S. scovelli* is considerably greater than the difference in adult size or in egg diameter; therefore, fecundity is greater in this species than in *S. scovelli*. Fertilized eggs of this species range from 0.6 to 1.2 mm in diameter. Average diameter lies between 0.8 and 0.9 mm. The young absorb the yolk sac prior to birth, and they measure about 11 mm at birth.

Length-frequency distributions reveal that maximum size attained by *S. floridae* in the Cedar Key area lies in the 200 to 210 mm range. Most of these large individuals are females. In spring a reproductive class of adults in the 130 to 160 mm range populate the flats. These adults disappear by late summer and are replaced by a large group of immature fish born in spring. These immature young grow to sexual maturity and breed in fall. A limited number of young born in fall overwinter and form the breeding class of the following spring. Apparently most individuals mature, breed, and die within a year of birth.

Small shrimp and mysids are the most important items in the diet of *S. floridae*. Amphipods and copepods are also taken often, but these organisms do not assume the importance in the diet of this species that they do in *S. scovelli*. Isopods, ostracods, larval decapods, and larval pipefishes are eaten occasionally by *S. floridae*. Seasonal changes in diet include an increase in the variety of items taken in summer and fall, a summer and fall increase in the utilization of small shrimp, and a summer and fall decrease in the consumption of copepods. Changes in the diet of *S. floridae* according to stages of its life cycle are less pronounced than in *S. scovelli*. Small shrimp are utilized frequently by all sizes, although consumption of shrimp is greatest by adults over 130 mm in length. The utilization of amphipods is nearly constant for all size classes. The consumption of copepods decreases in adults, but these organisms are never consumed as frequently by this species as by *S. scovelli*.

Syngnathus louisianae (Chain Pipefish)

A comparison of two populations of *S. louisianae* from Cedar Key and Biscayne Bay yielded several significant differences in morphology. Fish from Biscayne Bay tend to have longer trunk lengths, predorsal lengths, and head lengths than those from Cedar Key. Trunk rings, pectoral fin rays, and dorsal fin rays are also more numerous on Biscayne Bay specimens, but fish from Cedar Key exhibit a larger number of tail rings. These limited data are used only to suggest the possibility of genuine geographical variation in morphology in the Chain pipefish.

S. louisianae evidently is rare at most localities. Only 18 specimens were collected at Cedar Key during summer and fall in this investigation. Most museum collections contain only one to a few specimens. This species may be more common in deeper areas. The deepest record encountered in this study was a specimen taken in 20 fathoms off the coast of North Carolina.

Reproduction is difficult to study in S. louisianae because of its relative paucity in collections. No individuals in breeding condition were encountered at Cedar Key, but eight mature males and seven ripe females from other Florida localities were examined. Data from this small sample indicate that S. louisianae probably matures in the 150 to 200 mm size range. Pregnant males were collected during the months of January, April, August, and December, indicating that breeding probably occurs year round in Florida waters. Fertilized eggs are arranged in eight to twelve rows in the brood pouch. Six pregnant males of S. louisianae carried a mean of 664.7 eggs per pouch and a maximum of 898. Fertilized eggs vary from 0.6 to 1.4 mm in diameter, with an average diameter of approximately 1.0 mm.

Age and growth were impossible to analyze in S. louisianae because too few specimens were available. The maximum length of specimens taken at Cedar Key was 206.0 mm. The diet of S. louisianae closely resembles that of S. floridae. Small shrimp, mysids, and amphipods are the most frequently utilized items, with shrimp constituting the bulk of the diet because of their greater mass. Copepods and isopods are taken occasionally.

Micrognathus crinigerus (Fringed Pipefish)

Populations of M. crinigerus from Cedar Key and from the Florida Keys were compared morphologically. Trunk length, predorsal length, head length, and snout length are significantly greater in the population from the Florida Keys. Conversely, specimens from Cedar Key exhibit a larger number of tail rings. As in S. louisianae, these data are used only to suggest the possibility of genuine geographical variation in morphology.

M. crinigerus is relatively scarce at Cedar Key. Only 27 specimens were taken there in summer and fall. The abundance of this species in museum collections suggests that it may be more common in the Florida Keys.

The investigation of reproduction in this species was also limited by the small number of specimens available. Only two sexually mature males, measuring 80.0 and 81.0 mm, were taken at Cedar Key. Mature males collected by other workers at various Florida localities measured from 60.0 to 76.5 mm in length. Adult females from Cedar Key and other Florida localities ranged from 60.5 to 79.5 mm. These data indicate that sexual maturity is attained at a minimum size of about 60 mm in both sexes. Males usually incubate a small number of eggs, and they are arranged in two to four rows. Only one pregnant male, with 24 eggs, was taken at Cedar Key. Nine other pregnant males from various Florida localities incubated an average of 21.7 eggs per pouch. Maximum number was 41. Fertilized eggs vary from 0.9 to 1.3 mm in diameter, with the average lying between 1.1 and 1.2 mm.

The limited number of specimens available prevented an analysis of age and growth in the Fringed pipefish. Maximum lengths of specimens from Cedar Key lie in the 80 to 85 mm range.

The diet of the diminutive *M. crinigerus* is very similar to that of immature *S. scovelli*. Copepods are the most frequently utilized item, but tiny amphipods constitute the bulk of stomach contents in many specimens because of their greater size. Isopods and ostracods are taken occasionally. Shrimp and mysids are rather large for the small mouth of this species; thus they seldom appear in stomach contents.

SUMMARY

Pipefishes form an important part of the ichthyofauna inhabiting grass flats in the eastern Gulf of Mexico. Four species (*S. scovelli*, *S. floridae*, *S. louisianae*, and *M. crinigerus*) occur regularly in the vicinity of Cedar Key, Florida. *S. scovelli* is distributed from the northern Florida Atlantic coast to southern Texas, Yucatan, and possibly Brazil, with freshwater populations present in the St. Johns and Santa Fe rivers, Florida, and Lake St. John, Louisiana. *S. floridae* is distributed from Chesapeake Bay and Bermuda through the Bahamas to Panama. The range of *S. louisianae* extends from Chesapeake Bay to Florida, Texas and Campeche, Mexico, and in Bermuda and Jamaica. *M. crinigerus* is distributed in the Bahamas and from Miami to Yucatan, and possibly to Brazil.

Each species is figured and described. Sexual dimorphism is demonstrated in *S. scovelli* and *S. floridae*. Available mature specimens of *S. louisianae* and *M. crinigerus* are too few in number for valid sexual comparisons.

A detailed study of *S. scovelli* over its Florida range reveals considerable geographical variation in morphology. Number of dorsal fin rays, the most variable character studied, and number of tail rings tend to increase in northward areas, suggesting a clinal pattern correlated with temperature. Head length/snout length ratio is lower in northern and freshwater populations, suggesting that both low temperature and decreased salinity result in the development of a longer snout. Tail length/trunk length ratio is also quite variable, but no geographical pattern is evident. Little variation is exhibited in number of trunk rings and pectoral fin rays.

Morphologically, the freshwater population in the Santa Fe River is the most distinct, which suggests the possibility of genetic isolation from saltwater populations in the Gulf of Mexico. No such isolation is apparent for the freshwater population in the upper St. Johns River, which varies only slightly from coastal populations.

In the vicinity of Cedar Key S. scovelli is the most abundant pipefish, followed by S. floridae, with both species being found on the flats throughout the year. S. louisianae and M. crinigerus are relatively scarce in this area.

The shallow areas inhabited by pipefishes present a rigorous environment. They are subject to strong tidal and wave action, and shallow flats are occasionally exposed during extremely low tides. Salinity and temperature are variable. The existence of freshwater populations of S. scovelli suggests that this species is more tolerant of variations in salinity than the other species, and the northward distribution of S. floridae and S. louisianae indicates that they possess a greater tolerance of low temperatures.

The species under investigation attain sexually maturity over a wide range of sizes. Generally, males of S. scovelli reach sexual maturity between the sizes of 60 and 100 mm, but females become sexually mature at a larger size. No females less than 80 mm in length exhibited any ovarian development in this study. Males and females of S. floridae usually attain sexual maturity by the time they are 140-150 mm in length, but immature specimens often range from 120 to 160 mm in length. S. louisianae probably matures in the 150-200 mm size range. The minimum size at which sexual maturity is achieved by M. crinigerus seems to be about 60 mm for both sexes.

Nearly continuous breeding is indicated in many areas for these pipefishes. Pregnant males and ripe females of S. scovelli and S. floridae occurred at Cedar Key during all seasons, with spring and fall peaks in reproduction indicated for both species. The study of seasonal reproductive activity in S. louisianae and M. crinigerus was limited by the paucity of specimens, but S. louisianae probably breeds year around. M. crinigerus apparently has a shorter spawning season, lasting from April through September.

Sex ratio varies seasonally in S. scovelli and S. floridae. At Cedar Key sexually mature females of S. scovelli slightly outnumbered sexually mature males from late fall to early spring, but males greatly outnumbered females from late spring through early fall. In S. floridae females exceeded males in numbers during every month in which adults were encountered, except one. This difference was greatest in winter; during summer females outnumbered males only slightly.

The number of embryos carried by pregnant males depends largely upon the size of the male. Maximum brood counts obtained in this study were 175 embryos for S. scovelli, 886 for S. floridae, 898 for S. louisianae, and 41 for M. crinigerus.

Length-frequency analyses of Cedar Key specimens indicate that S. scovelli and S. floridae grow to sexual maturity and breed within a year of birth. It is doubtful that many individuals live much longer than a single year. Age and growth in *S. louisianae* and *M. crinigerus* are probably similar to that in *S. scovelli* and *S. floridae*.

The diet of these four pipefishes consists almost entirely of microcrustaceans. Generally, larger individuals utilize mainly amphipods and small shrimp, and smaller specimens feed on copepods and amphipods. This transition in diet according to size is demonstrated in *S. scovelli* and *S. floridae*. Other food items taken occasionally include isopods, ostracods, and larval pipefishes. The relative importance of each type of food organism varies among the four species, which should reduce interspecific competition for food.

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BIOGRAPHICAL SKETCH

James Dalton Brown was born January 5, 1943, at Robersonville, North Carolina, where he resided until his graduation from Robersonville High School in 1961. He attended North Carolina State of the University of North Carolina from 1961 to 1965 during which time he earned a Bachelor of Science in zoology. The next two years were spent at the University of Arkansas where he earned a Master of Science in zoology. While at the University of Arkansas he worked as a teaching assistant in the Department of Zoology during the first year and as a research assistant in the Water Resources Research Center during the second year. From 1967 to 1970 he attended the University of Florida and worked toward a degree of Doctor of Philosophy in zoology. During these three years he held a Graduate School Fellowship for one year and served a year each as a museum assistant in the Florida State Museum and as a teaching assistant in the Department of Biological Sciences. In August, 1970, he accepted a position as an Assistant Professor of Biology at Indian River Community College where he is still employed.

James Dalton Brown is married to the former Patsy Stevenson Bowling, and they have one daughter. He is a member of the American Fisheries Society and the American Society of Ichthyologists and Herpetologists. He also holds membership in the honorary organizations Phi Kappa Phi, Sigma Xi, Phi Sigma, and Gamma Sigma Delta.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Carter R. Gilbert

Carter R. Gilbert, Chairman
Associate Professor of Zoology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

William E. S. Carr

William E. S. Carr
Associate Professor of Zoology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Hugh D. Putnam

Hugh D. Putnam
Professor of Environmental Engineering

This dissertation was submitted to the Department of Zoology in the College of Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1972

Dean, Graduate School

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